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Phytoplankton Distribution and Productivity in Barkley Sound and Alberni Inlet: April 1987 Survey for the Marine Survival of Salmon Program

E. A. MacIsaac, M. C. Gollner, and J. R. Forbes

Biological Sciences Branch
Department of Fisheries and Oceans
West Vancouver Laboratory
4160 Marine Drive, West Vancouver
British Columbia V7V 1N6

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PHYTOPLANKTON DISTRIBUTION AND PRODUCTIVITY IN BARKLEY SOUND AND ALBERNI INLET: APRIL 1987 SURVEY FOR THE MARINE SURVIVAL OF SALMON PROGRAM

by

E. A. MacIsaac, M. C. Gollner, and J. R. Forbes[1]

Biological Sciences Branch
Department of Fisheries and Oceans
West Vancouver Laboratory
4160 Marine Drive
West Vancouver, British Columbia V7V 1N6

[1]Institute of Ocean Sciences
P.O. Box 6000
860 West Saanich Road
Sidney, British Columbia V8L 4B2

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ABSTRACT

MacIsaac, E. A., M. C. Gollner, and J. R. Forbes. 1991. Phytoplankton distribution and productivity in Barkley Sound and Alberni Inlet: April 1987 survey for the Marine Survival of Salmon Program. Can. Tech. Rep. Fish. Aquat. Sci. 1802: 61 p.

The distribution and productivity of phytoplankton in Barkley Sound and Alberni Inlet were surveyed April 22-30, 1987, prior to the spring migration of sockeye salmon (*Oncorhynchus nerka*) smolts through the area. Salinity variations due to freshwater inflows largely determined the density structure of the sound and inlet in April. Transects for vertical profiles of *in vivo* chlorophyll fluorescence showed significant spatial variability in phytoplankton standing stocks throughout the sound and inlet, and high temporal variability near areas of strong tidal mixing. Deep chlorophyll maxima were a common feature in Barkley Sound adversely affecting aerial or sea-surface mapping of chlorophyll distributions in the area. Size-fractioned chlorophyll and primary production revealed considerable variations in the biomass and primary productivity of different plankton size-fractions in the sound and inlet. Picophytoplankton (0.2-2 μm) were a minor component of phytoplankton biomass and production in April, while nano- and microphytoplankton dominated phytoplankton biomass and production respectively. Bacteria (and possibly detritus) dominated the 0.2-2 μm fraction but nanophytoplankton composed most particulates between 2 and 20 μm, with variable amounts of microzooplankton contributing to the 20-200 μm microplankton fraction. Size-fractionation of chlorophyll and particulate carbon, nitrogen, and phosphorus showed the need to isolate phytoplankton-rich size-fractions for particulate elemental analysis and for estimation of plankton chemical stoichiometry. Retention by glass-fibre filters of dissolved and colloidal organics passing 0.2-μm filters was found to be a significant methodological artifact. The distribution and levels of chlorophyll, primary production, bacteria abundance, and nutrient depletion showed the spring phytoplankton bloom was in progress throughout the study area in late April. Zones of high phytoplankton productivity were found in Barkley Sound and outer Alberni Inlet, while freshwater inflows curbed primary productivity at the head of Alberni Inlet. Although regions of Barkley Sound and outer Alberni Inlet were highly productive in late April, the survey showed the importance of timing plankton surveys relative to the spring phytoplankton bloom and the effects on the spatial distribution and levels of phytoplankton productivity and abundance recorded.

Key words: biological oceanography, primary production, phytoplankton, sockeye salmon (*Oncorhynchus nerka*), Barkley Sound, Alberni Inlet

RÉSUMÉ

MacIsaac, E. A., M. C. Gollner, and J. R. Forbes. 1991. Phytoplankton distribution and productivity in Barkley Sound and Alberni Inlet: April 1987 survey for the Marine Survival of Salmon Program. Can. Tech. Rep. Fish. Aquat. Sci. 1802: 61 p.

La distribution et la productivité du phytoplancton dans le bassin Barkley et l'inlet Alberni ont été évaluées du 22 au 30 avril 1987, avant le passage dans cette région, lors de leur migration printanière, des smolts de saumon rouge (*Oncorhynchus nerka*). En avril, les variations de salinité attribuables aux apports en eau douce ont largement déterminées la structure de densité des eaux du bassin et de l'inlet. Les profils verticaux de fluorescence de chlorophylle *in vivo*, établis au moyen de transects, ont révélé l'existence d'une importante variabilité spatiale des stocks de phytoplancton présents durant cette période dans l'ensemble du bassin et de l'inlet, et de fortes variations temporelles près des secteurs où les marées provoquaient un intense mélange des eaux. Les plus fortes concentrations de chlorophylle étaient souvent en profondeur dans le bassin Barkley, ce qui a nui à l'établissement par voie aérienne ou par bateau des distributions de chlorophylle dans cette région. La division du phytoplancton en classes fondées sur la taille et l'évaluation de la production primaire ont révélé l'existence de variations considérables dans la biomasse et la productivité primaire des diverses fractions phytoplanctoniques aux deux endroits. La contribution du picophytoplancton (0,2-2 µm) à la biomasse et à la production de phytoplancton était faible en avril tandix que le nano- et le microphytoplancton étaient responsables de la plus grande partie de la biomasse et de la production, respectivement. La classe 0,2-2 µm étaient principalement composée de bactéries (et peut-être de détritus), le nanophytoplancton représentait la plus grande partie des particules de 2 à 20 µm et le microplancton (20 à 200 µm) comportait des quantités variables de microzooplancton. L'analyse granulométrique de la chlorophylle et du carbone, de l'azote et du phosphore particulaires et l'estimation de la stoechiométrie chimique du plancton. La rétention par les filtres en fibre de verre de substances organiques dissoutes ou colloidales sur filtre de 0,2 µm s'est avérée un important artéfact méthodologique. La distribution et les quantités de chlorophylle, la production primaire, l'abondance des bactéries et l'appauvrissement des eaux en substances nutritives témoignaient du fait que la prolifération printanière du phytoplancton était en cours dans toute l'aire d'étude à la fin d'avril. On a repéré des zones où la productivité était élevée dans le bassin Barkley et à l'embouchure de l'inlet Alberni, mais la productivité primaire à la tête de cet inlet était réduite en raison des apports en eau douce. Bien que la productivité ait été très élevée dans le régions du bassin Barkley et de l'embouchure de l'inlet Alberni, la présente étude a montré l'importance de mettre en relation les études sur le plancton au momemt de la prolifération printanière du phytoplancton avec les effets sur la distribution spatiale et les taux de productivité et les abondances de phytoplancton measurés.

INTRODUCTION

Very little is known about the oceanographic factors affecting the early marine growth and survival of salmon. The potential importance of oceanographic events to the productivity of salmon is suggested by the large fluctuations in rates of marine survival exhibited by many British Columbia salmon stocks. In 1986, the Marine Survival of Salmon Program (MASS) undertook to examine physical and biological oceanographic factors that may be important to the survival of salmon during their early marine life. Among those salmon stocks chosen for detailed study were sockeye salmon (*Oncorhynchus nerka*) originating from the Barkley Sound and Alberni Inlet region on the west coast of Vancouver Island.

As planktivores, the temporal and spatial abundance of their zooplankton food may affect the dispersal, feeding, and survival of juvenile sockeye salmon entering the coastal marine environment in the spring. If juvenile sockeye congregate and feed in areas of high plankton abundance, interannual variations in the oceanographic conditions determining the foodchain productivity in these areas could affect their early marine growth and survival. Similarly, this interannual variability can alter the temporal productivity and development of spring plankton populations. The optimum abundance of zooplankton food may be in or out of phase with the migration of sockeye smolts through feeding areas.

In April 1987, we undertook an initial survey cruise of Barkley Sound and Alberni Inlet to determine the magnitude and spatial variability of plankton productivity and abundance in the region immediately prior to the spring smolt migration. Concurrently, other researchers tracked the migration of juvenile sockeye through the system and conducted aerial mapping of surface chlorophyll and temperature. One objective of these studies was to determine whether areas of high plankton productivity and abundance are present and correlated with the distribution of migrating schools of sockeye. This report presents primary production, phytoplankton biomass, and nutrient and particulate chemistry data for Barkley Sound and Alberni Inlet in late April. Depth profiles of *in vivo* chlorophyll fluorescence were also collected throughout the area along CTD transects for physical oceanographic data. Forbes et al. (1990) report the zooplankton abundance, size, and biomass data collected concurrently.

DESCRIPTION OF STUDY AREA

Alberni Inlet and Barkley Sound are on the west coast of Vancouver Island and were described by Tully (1949) and Waldichuk (1956a). The inlet is a fjord with two-layer estuarine flow driven by freshwater discharges from the Somass River at its head and runoff from smaller rivers discharging along its length (Fig. 1). Alberni Inlet is connected to the Pacific Ocean by Barkley Sound, which has three main channels; Trevor, Imperial Eagle, and Loudoun. The exchange of deep water in the sound and inlet is dependent on seasonal upwelling along the west coast of Vancouver Island (Bell 1976). The area supports important commercial and recreational fisheries for Pacific salmon, anadromous trout, herring, and groundfish. At the head of the inlet is a pulp and paper mill that discharges organic effluents into the surface waters of the inlet (Waldichuk 1956b, Parker and Sibert 1973, 1976). Organic mill effluents have a significant negative effect on the phytoplankton productivity of the upper estuary by attenuating light and enhancing heterotrophic competition for available nutrients (Parker et al. 1975). Waldichuk (1956a)

examined the chemical oceanography of Alberni Inlet and Trevor Channel, and many chemical and biological studies were conducted in Alberni Inlet examining the impacts of pollution from the pulp mill (Morris and Leaney 1980). However, the biological oceanography of Barkley Sound has not been studied in detail.

METHODS

Plankton studies were conducted from April 22 to 30, 1987, using the ship and laboratory facilities of the C.S.S. Vector. Each day, one of nine stations (B1 to B9) was occupied for detailed sampling and *in situ* incubations for phytoplankton production measurements (Fig. 2). After completion of the station, vertical casts for CTD physical structure and profiles of relative *in vivo* chlorophyll fluorescence (IFL) were conducted at stations along transects through Alberni Inlet (Stations A1-A11), Trevor Channel (T0-T7), Imperial Eagle Channel (I1-I9), and Loudoun Channel (L1-L13). Vertical profiles of *in vivo* chlorophyll fluorescence (IFL) were obtained using an *in situ* fluorometer (EOS Electro-Optik) at each CTD cast station. Temperature and salinity data obtained at each productivity station and along the CTD transects were converted to profiles of sigma-t density. Vertical light-profiles were measured at each productivity station with a Li-Cor model 185A light-meter equipped with a 192S underwater quantum-sensor (400-700 nm photosynthetically-active radiation). Vertical light-extinction coefficients were calculated from linear regressions of ln (light intensity ($\mu E\ m^{-2}\ s^{-1}$)) versus depth. The depth of the euphotic-zone (compensation depth) was estimated as 1% of surface light intensity.

At each productivity station, samples for chemical and biological measurements and primary productivity incubations were collected with 4-L Niskin bottles at eight discrete depths from the surface to below the euphotic-zone (15 or 20 m). Additional Niskin casts at three depths in the euphotic-zone were made and clean 12-L polyethylene carboys were rinsed and filled. The 12-L samples were screened through 200-μm Nitex to remove macrozooplankton and used for size-fractionation of particulate carbon, nitrogen, phosphorus, and chlorophyll.

In situ primary production was measured by rinsing and filling two 300-mL polycarbonate light bottles and one dark bottle with water from each of eight depths. Bottles were inoculated with 0.2 MBq of a [^{14}C] sodium bicarbonate solution filtered (0.2-μm membrane filter) prior to inoculation. Bottles were suspended horizontally in plexiglass holders and incubated *in situ* at their respective depths for 1.5 h between 0930 and 1130 h. After incubation, bottles were recovered into coolers and subsampled for total ^{14}C specific activity. Specific activity was determined by withdrawing 500-μL aliquots for liquid scintillation analysis from randomly selected incubation bottles. Eighty-millilitre aliquots from each bottle were filtered (<20-cm Hg) onto 0.2-μm and 2.0-μm Nuclepore polycarbonate filters (47-mm diameter) and 20-μm Nitex nylon screens to size-fractionate the ^{14}C uptake. Filters were removed under vacuum without rinsing, and placed into scintillation vials containing 500 μL of Scintigest (Fisher) to dissolve the polycarbonate filters and trap CO^2. After each filter dissolved, 10 mL of Scintiverse II (Fisher) scintillation cocktail was added. Vials were counted in a Packard Tri-Carb 4530 Liquid Scintillation Counter, and counts were corrected using quench series constructed from the same filters and scintillation cocktails.

Glass bottles (300 mL) were rinsed and filled with water from each depth. A Radiometer Model PHM84 pH meter was used to determine pH and total alkalinity using the methods of Strickland and Parsons (1972). Dissolved

inorganic carbon was determined indirectly from pH, temperature, and total alkalinity. Rates of primary production (mgC m^{-3} h^{-1}) were calculated as described by Strickland and Parsons (1972). Bacteria and phytoplankton samples were collected at four of the eight production depths and the plankton size-classes used in this report follow those defined by Sieburth et al. (1978). Samples for enumerating nanophytoplankton (2-20 μm) and microphytoplankton (20-200 μm) were collected in clean 100-mL amber glass-bottles and preserved with Lugol's acetic-acid solution (data not reported).

Bacteria were enumerated using the Acridine Orange method of Hobbie et al. (1977) as modified by MacIsaac et al. (1981). A 5-mL sample was filtered onto a 25-mm diameter, 0.2-μm Nuclepore polycarbonate filter previously stained with Irgalan Black (2 g L^{-1} in 2% acetic acid). Filters were air-dried and stored at 20°C in opaque petri dishes lined with absorbent filter paper. For enumeration, each filter was placed in a 25-mm filter holder. Bacteria were rehydrated and stained for 3-5 min by addition of 1 mL of Acridine Orange solution (0.05 g L^{-1}), then rinsed with 5-mL of deionized, distilled water (DDW). Stain solutions and rinse water were filtered through sterile 0.2-μm Sartorius membrane filters prior to use. Damp filters were mounted on glass slides with non-fluorescent immersion oil. Bacteria were enumerated at 1250 X magnification using a Zeiss epifluorecence microscope equipped with a 450-490 nm bandpass filter, a 510-nm beam splitter, and a 520-nm barrier filter. Random fields were counted until 400 bacteria or 10 fields were enumerated.

Picophytoplankton (0.2-2 μm) were enumerated using epifluorescence and broad-band excitation as described by MacIsaac and Stockner (1985). A 15-mL sample was filtered onto a prestained 25-mm diameter, 0.2-μm Nuclepore filter and air-dried in the dark at room temperature in an opaque petri dish. Exposure of the sample to light was minimized during sample processing. Autofluorescent picophytoplankton were enumerated by placing the filter in a 25-mm filter holder and rehydrating the cells with 1 mL of DDW for 3-5 min. The DDW was drawn through and the moist filter was mounted as described for bacteria. The Zeiss epifluorescence microscope was equipped with a 397-560 nm bandpass filter set, a 580-nm beam splitter, and a 590-nm barrier filter. Random fields were counted until 200 cells or 10 fields were enumerated.

Concurrent with sampling for primary production measurements, additional samples were taken at each depth for chlorophyll and nutrient analyses. Chlorophyll was collected by filtering 500-mL samples onto 47-mm diameter, 0.45-μm Millipore AA filters with two drops of saturated $MgCO^3$ suspension added during filtration. Filters were folded and stored frozen prior to extraction in 90% acetone. Chlorophyll concentrations were measured without a phaeophytin subtraction using a Turner Model III fluorometer (Stephens and Brandstaetter 1983).

Samples were collected in 50-mL glass tubes for nitrate-nitrite and orthophosphate analysis and in 20-mL polystyrene tubes for reactive silicate analysis, and closed with teflon-lined caps. Tubes were acid-cleaned and rinsed three times with sample water prior to filling. Samples were quick frozen in a -40°C alcohol bath and stored. Technicon Auto-Analyzer II methods were used for all nutrient analyses. Orthophosphate was analyzed as the molybdate complex using the ascorbic-acid reduction method of Brynjolfson (1973) without a turbidity correction. Nitrate-nitrite and reactive silicate were determined using Technicon Industrial Methods 186-72 W and 158-71 W (1977). Samples were thawed according to Macdonald et al. (1986) and mixed prior to analysis. Working standards were calibrated against certified Sagami standards. All glass and plastic materials used for nutrient analyses were soaked overnight in 1M hydrochloric acid and rinsed three times with deionized water. Previous analyses of replicate samples (Denman et al. 1985) determined an expected percentage error for nitrate-nitrite of 14.3%, 9.4% for orthophosphate, and 11.5% for reactive silicate, with detection limits of 0.1,

0.01, and 0.2 μg-at L^{-1} respectively.

Size-fractionation of particulate carbon (PC), nitrogen (PN), phosphorus (PP), and chlorophyll was conducted on the 12-L water samples collected at all production stations except B8. Chlorophyll, PC, PN, and PP passing selected polycarbonate filters or nylon screens were analyzed to determine the chemical composition of particulates in different size-fractions. Particulates passing a 200-μm Nitex mesh were used as the total particulate fraction since comparison of chlorophyll levels in screened and unscreened samples showed a 200-μm mesh removed the macrozooplankton but not a significant amount of chlorophyll from the samples (Fig. 3). Subsamples of 2.5 L were filtered through Nuclepore polycarbonate filters of 0.2-μm or 2.0-μm pore size, or Nitex nylon screens of 20-μm mesh, with the filtrate from each retained for analysis. Filtrates were collected in clean glass filtration flasks using polysulphone (Nalgene) filter holders. Chlorophyll was determined by filtering 500 mL of each filtrate onto 0.45-μm Millipore AA filters for analysis as previously described. PC and PN were collected by filtering 1 L of filtrate onto precombusted (4h at 460°C) Whatman glass-fibre filters (GF/F, 47-mm diameter) and stored frozen in aluminum dishes. For PP measurements, 1 L samples were filtered onto precombusted GF/F filters and stored in clean glass vials. PC and PN analyses were conducted using a CEC Perkin Elmer Model 240 CHN analyzer and corrected for filter blanks. PP samples were analyzed using the combustion and ascorbic-acid reduction method of Stainton et al. (1977) using filters washed with DDW as blanks.

Euphotic-zone means were calculated by depth integration of data profiles to the compensation depth or by averaging data for the three euphotic-zone depths sampled at each station. Data less than the detection limit of the method were assigned zero values for integration and averaging.

Euphotic-zone averages of primary production, chlorophyll, bacteria, and nutrient levels at stations B1 to B9 were converted to relative, normalized parameters to compare phytoplankton production in the sound and inlet. Bacteria and nutrient levels in the various waters were used as an indirect index of the primary production contributed by spring phytoplankton blooms prior to the cruise. Bacteria are an integral part of the carbon-cycling processes in pelagic waters and bacterial abundance is well correlated with phytoplankton productivity in both freshwater and marine environments (Bird and Kalff 1984). Nutrient supply is an important growth-limiting factor for phytoplankton in coastal British Columbia waters (Harrison et al. 1983) and the depletion of nutrients in the surface waters was used to indicate the magnitude of spring phytoplankton growth. Normalized bacteria and nutrient depletion parameters were termed *recent productivity* indicators, reflecting the *recent*, cumulative primary productivity of the sampled waters at each station. Chlorophyll and primary production parameters were *current productivity* indices, indicating relative levels of phytoplankton biomass and production measured at the time of the cruise. Normalized productivity parameters scaled from 0 to 1, with 0 assigned to the station with the lowest recorded value of the variable and 1 to the highest. Normalized parameters were calculated by the equation: $(X - X_{min})\ (X_{max} - X_{min})^{-1}$ where X is the variable value for a station, and X_{min} and X_{max} were the highest and lowest values for that variable among stations. The normalization procedure was inverted for the nutrient-depletion parameter, since nutrient depletion ensues from high phytoplankton productivity, using the equation: $(X_{max} - X)\ (X_{max} - X_{min})^{-1}$. Mean euphotic-zone concentrations for nitrate, phosphate, and silicate covaried among stations ($r = 0.85$-0.97), so each nutrient variable was normalized and the average of the three reported as the nutrient-depletion parameter for each station.

RESULTS AND DISCUSSION

CTD AND *IN VIVO* CHLOROPHYLL TRANSECTS

Salinity variations due to mixing with freshwater inflows largely determined density structure and stratification in the surface waters (0-20 m) of Alberni Inlet and Barkley Sound in April (Tables 1A-9A). Regional variations in near-surface temperatures were small, ranging from 11.2-12.3 °C in Alberni Inlet and Trevor Channel to 9.6-10.7 °C in Imperial Eagle and Loudoun Channels and off Amphitrite Point. However, surface salinities varied widely from a low of 8.5 ‰at the head of Alberni Inlet near the mouth of the Somass River to 30.5 ‰off Amphitrite Point.

The Alberni Inlet transect showed a typical estuarine physical structure with a brackish surface layer increasing in depth and salinity down the inlet (Fig. 4). A strong pycnocline was present at a depth of 1.5-7 m down the length of the inlet. *In vivo* chlorophyll fluorescence (IFL) was very low at the head and significant IFL levels were only recorded in the surface waters of the mid-inlet where salinities exceeded 20 ‰.IFL levels in Trevor Channel were similar to or higher than in the outer inlet (Fig. 5). The highest *in vivo* chlorophyll levels of the Trevor Channel transect were found near the mouth of Barkley Sound, with the chlorophyll concentrated in subsurface IFL maxima at 4-7 m depth.

Surface salinities along the Imperial Eagle Channel transect increased from Junction Passage to outer Barkley Sound, reflecting the reduced effects of freshwater inflows on density stratification in the outer sound (Fig. 6). Chlorophyll was restricted to the top 5 m of water in areas near strong tidal mixing in Junction Passage, but was concentrated in subsurface IFL maxima at 4-10 m depth in the rest of the channel and outer sound. Average *in vivo* chlorophyll in the water column generally decreased seaward from Junction Passage to the mouth of Barkley Sound.

The transect through Loudoun Channel to the mouth of Barkley Sound showed the greatest regional variations in *in vivo* chlorophyll levels observed during the cruise (Figs. 7 and 8). Subsurface IFL maxima were present at all stations. From inner Imperial Eagle Channel through the island passages to inner Loudoun Channel, the salinity of the surface waters and the IFL levels in the subsurface maxima (4-6 m) increased, with large subsurface chlorophyll concentrations peaking at 4-12 m depth in the inner channel. High subsurface IFL maxima persisted through Loudoun Channel to outer Barkley Sound with some of the highest *in vivo* chlorophyll levels of the cruise recorded in the outer channel and sound.

Repeated sampling of three stations over the duration of the cruise showed significant short-term temporal variability in the magnitude and structure of the *in vivo* chlorophyll profiles near areas of tidal mixing, but not in the more stable waters of the salinity-stratified inlet or the open waters of the outer sound. CTD and IFL profiles were collected 1-5 days apart during different transects (Figs. 4-8) at outer Alberni Inlet (Station A11, T0, and I1), inner Imperial Eagle Channel (I5 and L1), and at the mouth of Barkley Sound (I9, T7, and L13). CTD and IFL vertical profiles at the outer Barkley Sound station were similar among sampling dates, indicating some short-term temporal stability in the open waters of the channels. Chlorophyll profiles in outer Alberni Inlet were also comparable among sampling dates, with the chlorophyll largely concentrated in the brackish surface layer. In contrast, there were large differences in IFL structure between sampling dates at the inner Imperial Eagle Channel station, ranging from very low *in vivo* chlorophyll with little subsurface structure to high chlorophyll levels with a

broad subsurface peak at 5-10 m. The waters of the inner channel are directly influenced by tidal displacement and advection of water from areas of strong tidal mixing in the nearby passages, and high temporal instability would be expected in waters of the sound near zones of turbulent mixing.

The IFL transects showed significant spatial variations in chlorophyll levels throughout Barkley Sound and Alberni Inlet and high temporal variability in IFL structure near areas of strong tidal mixing. Based on the *in vivo* chlorophyll surveys alone, Loudoun Channel, inner Imperial Eagle Channel, and outer Barkley Sound had the highest chlorophyll standing stocks in late April, with the bulk concentrated in subsurface maxima. Relative *in vivo* chlorophyll levels generally were comparable to extracted chlorophyll concentrations in concurrent discrete samples, although values could occasionally differ significantly at individual depths (Fig. 9). Thus, the regional variations in IFL levels recorded likely reflect genuine differences in the chlorophyll content of the various waters. However, the high *in vivo* chlorophyll levels recorded in the subsurface maxima may exaggerate actual regional differences in phytoplankton biomass because of the high chlorophyll:biomass ratios typically found in deep concentrations of phytoplankton (Cullen 1982). The ubiquity of subsurface chlorophyll maxima in Barkley Sound may also limit the usefulness of remote-sensing or sea-surface sampling techniques for mapping areal phytoplankton biomass (e.g. Parsons et al. 1981) since the bulk of the water-column chlorophyll would be missed by the measurements.

LIGHT AND NUTRIENT LEVELS

Most of the subsurface chlorophyll maxima recorded in Barkley Sound were located at or above the compensation depth of the euphotic-zone, indicating ambient light levels were adequate for net primary production within most IFL maxima. Euphotic-zone depths ranged from 5.1-7.7 m in Alberni Inlet, Trevor Channel, and inner Imperial Eagle Channel, to 9.1-10.0 m in Loudoun Channel and outer Barkley Sound (Tables 1A-9A). Light extinction coefficients varied from 0.47-0.65 in Alberni Inlet to a high of 0.98 in Trevor Channel, with lows of 0.39-0.49 in Loudoun Channel and outer Barkley Sound. The light profile at the head of Alberni Inlet was not log-linear due to high light-extinction by organic pulpmill effluents concentrated in the brackish surface layer.

Vertical profiles of silicate, nitrate, and phosphate exhibited significant depletion in the surface waters throughout Barkley Sound and Alberni Inlet (Tables 1A-9A). The degree of nutrient depletion suggests that the spring phytoplankton bloom was well underway by late April throughout the sound and outer inlet. However, low nitrate and phosphate levels (1.8-7.7 and 0.3-1.0 μg-at L^{-1}, respectively) at the head of Alberni Inlet (Table 1A) largely result from dilution by nutrient-poor freshwater from the Somass River (Table 10) and from biological uptake by heterotrophic bacteria. Parker et al. (1975) studied pulpmill pollution in the inlet and concluded that bacteria decomposing the organic effluents were responsible for a large part of the biological consumption of nitrate in the surface waters at the head of Alberni Inlet. Using nitrate and salinity values from the Somass River and from 10-15 m depth in the inlet as the source of entrained saltwater, we estimate that dilution by freshwater accounted for less than 45% of the nitrate depletion observed in the surface waters (0-2 m) at the head of the inlet in late April. Biological sequestering was apparently responsible for a significant part of the nutrient depletion observed in the surface waters in spring. Since *in vivo* chlorophyll levels were very low at the head of the inlet, phytoplankton were likely not responsible for the bulk of the nutrient uptake. As well, silicate levels in the river and the entrained saltwater were similar (36-40 μg-at L^{-1}) and vertical profiles at the inlet head exhibited little depletion in the

surface waters indicative of significant phytoplankton (diatom) production. The nutrient data therefore support the conclusion of Parker et al. (1975) that bacterial activity, enhanced by the discharge of organic pulpmill effluent, was responsible for much of the nitrate depletion at the head of the inlet.

In the outer inlet and the sound, relatively high phytoplankton production was responsible for nutrient depletion in the surface waters (Tables 2A and 3A). Nitrate levels in the outer inlet were depleted below detection limits in the top 5m, and silicate and phosphate concentrations were also low (<6.5 and <0.9 μg-at L^{-1}, respectively). Nitrate was also at or below detection limits in the surface waters of Trevor and Loudoun Channels and outer Imperial Eagle Channel (Tables 4A-8A) and silicate and phosphate concentrations were <7.3 and <0.4 μg-at L^{-1} respectively.

The highest ambient nutrient levels in the euphotic-zone were recorded at inner Imperial Eagle Channel and off Amphitrite Point. The inner channel is directly influenced by nutrient-rich waters advected from areas of strong tidal mixing in nearby passages. Waters outside the mouth of Barkley Sound were weakly stratified in April and still subject to occasional wind-mixing of the water column and entrainment of nutrient-rich deep water. The surface waters outside the sound may also receive advected nutrient-rich water from oceanic upwelling along the continental shelf.

PHYTOPLANKTON CHLOROPHYLL AND PRIMARY PRODUCTION

The chlorophyll levels and primary production rates recorded in the sound and inlet in April were relatively high and similar to levels expected during spring bloom conditions in other coastal British Columbia waters (Harrison et al. 1983). Average chlorophyll levels ranged 5-fold from a low of 2.2 μg L^{-1} at the head of Alberni Inlet to highs of 10.3-12.5 μg L^{-1} in Trevor and inner Loudoun and Imperial Eagle channels, with intermediate levels (5.8-8.8 μg L^{-1}) in the rest of the inlet, the outer channels, and off Amphitrite Point (Table 11). Highest chlorophyll levels generally coincided with the lowest ambient nutrient levels. Mean euphotic-zone primary production (mgC m^{-3} h^{-1}) ranged 7-fold from a low of 3.8 at the head of Alberni Inlet to highs of 23.7-28.4 in mid-Alberni Inlet, inner Loudoun Channel, and off Amphitrite Point (Table 11). Productivity rates were intermediate (14.4-16.5 mgC m^{-3} h^{-1}) at the other stations. Primary production levels in Trevor Channel were anomalously low due to heavy fog and very low light conditions during the *in situ* incubation. Excluding this station, average primary production in the euphotic-zone was significantly correlated with mean chlorophyll levels (r=0.85).

Depth profiles of chlorophyll and primary production had similar vertical structures in both the sound and inlet, with deep chlorophyll maxima often contributing a significant portion of the total primary production in the water column of the sound (Fig. 10). Both stations in Loudoun Channel had pronounced subsurface IFL and primary production maxima at or below 5-m depth. The subsurface concentrations of chlorophyll in Barkley Sound clearly made a significant contribution to phytoplankton productivity in late April.

The nanoplankton (2-20 μm) and microplankton (20-200 μm) size-fractions dominated chlorophyll biomass and primary production throughout the sound and inlet, although the relative importance of each fraction to total chlorophyll and phytoplankton production varied widely among stations (Fig. 11). Picophytoplankton (0.2-2 μm) generally was a minor component of the total, contributing only 5-16% (mean 10%) of the chlorophyll and 5-37% (mean 15%) of the primary production. Nanophytoplankton accounted for an average of

53% (28-68%) of the chlorophyll but only 24% (4-62%) of the primary production. Phytoplankton in the microplankton size-fraction contributed a smaller proportion of the chlorophyll biomass (15-67%, mean 36%) but much of the primary production (26-90%, mean 60%). The contributions of the different size-fractions to chlorophyll biomass and primary production indicate a high degree of spatial variability in the size structure and productivity of the different phytoplankton assemblages in late April.

Primary production:chlorophyll ratios (assimilation ratios), measured between 0930-1130 h and averaged over the euphotic-zone, ranged from 1.6 to 3.0 mgC h^{-1} $mgChl^{-1}$ (excluding the anomalously low value for Trevor Channel). The lowest assimilation ratios were at the head of Alberni Inlet and at inner Imperial Eagle Channel. Highest ratios were found at the middle of Alberni Inlet and off Amphitrite Point. The very low assimilation ratio in Trevor Channel resulted from limitation of photosynthesis by low ambient light during the *in situ* ^{14}C incubation. Assimilation ratios are normalized photosynthetic rates used as indices of the turnover rate or growth potential of phytoplankton biomass (Eppley 1980). Low average euphotic-zone ratios usually indicate a slow-growing phytoplankton community strongly growth-limited by light, temperature, nutrients, or salinity (Harrison et al. 1983), or a vertically stratified phytoplankton community with chlorophyll concentrated in deep, light-limited maxima (Cullen 1982).

PICOPLANKTON

Densities of picophytoplankton from epifluorescence counts (>98% *Synechococcus* sp.) were consistently low throughout the sound and inlet and similar to the low abundances typically found in temperate coastal waters in early spring (Joint 1986, Waterbury et al. 1986). Mean euphotic-zone densities of picophytoplankton ranged from 1.2-6.6 10^3 mL^{-1}, with the lowest levels at the head of Alberni Inlet and off Amphitrite Point, and higher densities in the channels and outer Alberni Inlet (Table 11). The low abundance of picophytoplankton is consistent with the relatively small contribution of the picoplankton size-class to total chlorophyll and primary production throughout the sound and inlet (Fig. 10).

Bacteria densities were also typical of the relatively low spring levels found in temperate coastal waters (Fuhrman et al. 1980). Bacteria abundance was low (3.7-5.1 10^5 mL^{-1}) in inner Alberni Inlet, reaching densities of 7.8-12.9 10^5 mL^{-1} in the outer inlet and Barkley Sound. The euphotic-zone density of bacteria was negatively correlated with levels of nitrate, phosphate, and silicate (r= -0.87 to -0.90), indicating higher abundance in waters depleted of nutrients by phytoplankton production. The bacteria density in the brackish surface layer at the head of Alberni Inlet (6.7 10^5 mL^{-1}) was higher than expected from simple mixing of Somass River freshwater with entrained saltwater (ca. 3.0 10^5 mL^{-1} expected) (Tables 1 and 10). Since phytoplankton productivity was very low, high bacteria levels at the head of the inlet supports the conclusion that depletion of nitrate in the surface waters largely results from enhancement of bacterial activity by organic pulpmill effluents (Parker et al. 1975).

PARTICULATES

In general, particulate concentrations in the surface waters of the sound and inlet did not covary with chlorophyll levels (Tables 1B-9B). Phytoplankton biomass apparently was a highly variable fraction of the total

particulates in the surface waters in April. Average PC, PN, and PP levels in the 0.2-200 μm size-fraction (<0.2-μm fraction subtracted) ranged 2-3 fold among stations (Table 11). PC concentrations were lowest at the head of Alberni Inlet (335 μgC L^{-1}) and increased to highs of 849-992 μgC L^{-1} in the outer inlet and Trevor Channel. PC levels in the rest of Barkley Sound and off Amphitrite Point were intermediate in concentration (406-512 μgC L^{-1}). PN levels showed a similar trend, ranging from a low of 44.7 μgN L^{-1} at the head of the inlet to 79.7-118.3 μgN L^{-1} in the outer inlet and Trevor Channel, with levels in the rest of the sound of 64.0-93.7 μgN L^{-1}. PP levels did not closely parallel PC and PN levels among stations. PP concentrations varied from lows of 4.1-4.5 μgP L^{-1} in the waters of inner Alberni Inlet and Trevor Channel to 7.0-8.7 μgP L^{-1} in the outer inlet and Barkley Sound, with a high of 10.1 μgP L^{-1} in the open waters off Amphitrite Point.

Carbon:chlorophyll ratios are typically 25-50:1 (by weight) for phytoplankton with relatively high specific growth rates (Goldman 1980). The substantially higher ratios in the picoplankton and microplankton size-fractions at most stations indicate significant contributions by non-phytoplankton organic particulates (Fig. 12). PC:chlorophyll ratios were consistently high in the picoplankton fraction and ranged from 75:1 to 313:1 (mean 160:1), reflecting the low biomass of picophytoplankton but relatively high PC contribution by bacteria biomass (and possibly detritus). Ratios for the microplankton fraction ranged widely from 35:1 to 169:1 (mean 99:1). The highest values suggest significant particulate contributions by microzooplankton biomass passing the 200-μm prescreen at some stations. In contrast, the nanoplankton fraction showed a relatively narrow range of PC:chlorophyll ratios among stations of 42:1 to 68:1 (mean 53:1), similar to ratios expected for a size-fraction dominated by phytoplankton biomass.

Compared to the other size-fractions, the nanoplankton fraction was relatively low in non-phytoplankton particulates. This fraction was used to examine other chemical composition ratios (PC:PN, PN:PP) for evidence of nutrient deficiency in the phytoplankton in late April (Hecky and Kilham 1988). Healey and Hendzel (1980) concluded that phytoplankton with PC:PN ratios greater than 7:1 and PN:PP ratios higher than 10:1 are growth-limited by the availability of nitrogen. Nanoplankton PC:PN ratios were generally below 7:1 (5.1-7.2:1), with higher ratios (9.4-9.9:1) indicative of mild nitrogen limitation only found in outer Alberni Inlet and inner Loudoun Channel (Fig. 13). Phytoplankton PN:PP ratios were calculated by combining the picoplankton and nanoplankton size-fractions to reduce the high subsample variances from fractionating the relatively low total PP levels. Although this increased the particulate contributions from bacteria and detritus, the size-fraction was still enriched in phytoplankton biomass relative to the total particulate fraction. PN:PP ratios substantially greater than 10:1 and indicative of nitrogen-limitation of phytoplankton growth were only found in the surface waters of the outer inlet and in Trevor Channel (Fig. 14). Thus, despite the low nitrate levels recorded in the surface waters of the sound and inlet, strong and wide-spread nitrogen limitation of phytoplankton growth was not yet evident in late April. Based on elemental ratios, only phytoplankton in outer Alberni Inlet, and possibly Trevor and inner Loudoun channels, indicated any degree of nitrogen deficiency.

Of the 24 filter-fractionated chlorophyll and particulate water samples (Stations B1-B7 and B9), only 10 showed detectable levels of chlorophyll (>0.18 μg L^{-1}) passing the 0.2-μm polycarbonate filters and retained by the 0.45-μm chlorophyll filters (Tables 1B-7B and 9B). Chlorophyll in the <0.2-μm fraction only occurred in samples with high total chlorophyll levels (>7.0 μg L^{-1}) and accounted for only 4.5% (1.5-7.1%) of the total chlorophyll in these samples. This small amount of chlorophyll passing a 0.2-μm polycarbonate filter could result from the occasional flawed filter (Stockner et al. 1990) or from fragments of cells broken during filtration passing the 0.2-μm polycarbonate filters but retained by the 0.45-μm

chlorophyll filters (Li 1990). However, Taguchi and Laws (1988) found similar levels of chlorophyll passing 0.2-um polycarbonate filters in waters near Hawaii and attributed it to the low but finite probability that all filters pass a significant number of cells larger than their nominal pore-size that may be collected by subsequent filtrations.

Organic matter, passing 0.2-μm polycarbonate filters but retained by the glass-fibre filters used for PC/PN analyses (0.7-μm nominal pore-size), was a significant component of the total particulate samples at all stations. The <0.2-μm fraction contributed an average of 20% (13-28%) of the PC, 9% (6-13%) of the PN, and 8% (1-18%) of the PP in the <200-μm fraction (Tables 1B-9B). PC:PN ratios for the <0.2-μm fraction were 12-22:1 by weight (Fig. 13), well above the Redfield ratio for phytoplankton (5.7:1) (Redfield et al. 1963) and ratios reported for particulates in the open oceans (4.5-10.7:1) (Goldman 1980), but similar to ratios for terrestrial allochthonous organic matter (LaZerte 1983). PN:PP ratios were also significantly higher (10-20:1) than the Redfield ratio for phytoplankton of 7.2:1 (Fig. 14). Chlorophyll in this fraction was very low or undetectable, yielding very high PC:chlorophyll ratios of 200->1000:1. Coupled with the PC:PN and PN:PP ratios indicating organic matter high in carbon but very low in nitrogen and phosphorus, this fraction was clearly dominated by non-living organic matter and not plankton passing the 0.2-μm filters. Adsorption or retention by the glass-fibre filters of dissolved and colloidal organic matter passing the polycarbonate filters is the likely source of this abiotic "particulate" matter (Abdel-Moati 1990). Clearly, adsorption and colloidal retention of non-living "dissolved" organic matter is a significant methodological artifact affecting particulate measurements in these coastal marine waters. Fractionation and isolation of specific plankton size-fractions to obtain phytoplankton-rich fractions for elemental analysis is clearly required to estimate the chemical composition and stoichiometry of phytoplankton in coastal waters.

REGIONAL VARIATIONS IN PHYTOPLANKTON PRODUCTION

Very low chlorophyll and primary production at the head of Alberni Inlet but high phytoplankton biomass and production in the surface waters of the middle and outer inlet (Table 11, Fig. 4) is a spring distribution pattern typical of coastal British Columbia fjords with strong estuarine circulation patterns (e.g., Stockner et al. 1977). Relatively high freshwater discharge at the head of the inlet in April transports low-salinity surface water down the inlet, entraining saltwater and nutrients and improving conditions for the growth of phytoplankton in the brackish surface layer moving seaward. The developing phytoplankton populations were accompanied by increased bacteria levels and depletion of nutrients in the surface waters (Table 12). The distribution and levels of phytoplankton biomass and production down Alberni Inlet depend heavily on seasonal variations in freshwater discharges and surface outflow velocities that determine the salinity, stability, and depth of the euphotic zone, the entrainment of nutrients, and the transport of plankton in the surface waters down the inlet.

Barkley Sound showed 2-3 fold regional variations in phytoplankton chlorophyll and primary production with highest levels generally found in the relatively sheltered waters of Trevor and inner Loudoun channels (Table 11). However, the high levels of chlorophyll and primary production recorded in the sound, coupled with the degree of nutrient depletion recorded in the surface waters, indicate spring phytoplankton blooms were well in progress by late April. The regional variations in phytoplankton levels may only reflect interception of the vernal bloom at different stages of development in different areas of the sound. To evaluate the possible effects of bloom-timing on the observed regional variability, euphotic-zone nutrient depletion and

bacteria densities, as indirect indices of *recent* spring phytoplankton production occurring prior to the cruise, were compared to the *current* phytoplankton chlorophyll and production levels found during the cruise in the sound. The anomalous primary production data for Trevor Channel was ignored.

Relatively high bacteria densities and nutrient depletion, but low chlorophyll and primary production levels, would be indicative of post spring-bloom conditions in areas of the sound. Only outer Imperial Eagle Channel showed bacteria, nutrient depletion, and phytoplankton biomass and production levels indicative of late spring bloom conditions (Table 12). Thus for much of the sound, the cruise in late April apparently coincided with the peak development of the vernal bloom. However, stations in the sheltered waters of Trevor and Loudoun channels had relatively high chlorophyll levels largely concentrated in pronounced subsurface maxima, suggesting that vernal blooms had developed earlier and settled into deeper water layers in more sheltered and stable waters of the sound. The timing of a spring survey cruise relative to the vernal phytoplankton bloom largely determines whether regional differences reflect actual spatial productivity differences or merely seasonal and interannual temporal variability in the development of the spring phytoplankton bloom in different regions of the sound and inlet.

Over the growing season in coastal marine waters, heterogenous distributions of phytoplankton are typically generated by regional variations in physical turbulence and water column stability, and transported by tidal movements and the general circulation of the surface waters (Parsons et al. 1981, Harrison et al. 1983). Thus, high phytoplankton production is often found in stable nutrient-enriched waters near zones of frontal mixing and nutrient entrainment, while highly-turbulent unstable waters and nutrient-exhausted open waters are usually characterized by low phytoplankton production. However, during the spring transition period (March-May), phytoplankton blooms and nutrient-limitation are just developing, and regional differences in phytoplankton production driven by variations in the timing and development of euphotic-zone stability and the growth of spring phytoplankton, and not by nutrient supply. Thus the regional variations in phytoplankton biomass and production found in Barkley Sound and Alberni Inlet during the spring bloom do not reflect the type of spatial distribution in phytoplankton production found during the remainder of the growing season when nutrient supply and the location of mixing fronts (Parsons et al. 1981) may largely determine regional variations in phytoplankton production.

To link regional and temporal variations in phytoplankton production to the early marine survival of sockeye salmon will require detailed knowledge of the feeding ecology and foodweb dynamics of migrating sockeye after their entry into the marine environment. Interannual variability in the timing of vernal phytoplankton blooms in coastal waters, that confounds assessment of regional and annual variations in phytoplankton production, may be more important to the temporal development of zooplankton food resources for juvenile sockeye than the actual magnitude of the plankton production. The life-history, behaviour, and grazing strategies of the important zooplankton prey species will ultimately determine whether interannual and spatial variations in phytoplankton production are translated into variations in zooplankton resources for feeding juvenile salmon during spring migration (Parsons and LeBrasseur 1970, Harrison et al. 1983).

SUMMARY

The Barkley Sound and Alberni Inlet area is an important migration corridor for planktivorous sockeye salmon (*Oncorhynchus nerka*) smolts leaving the Somass River and Henderson Lake in the spring. The distribution and productivity of phytoplankton in the system was surveyed April 22-30, 1987, just prior to the start of the major spring smolt migrations.

Density structure in the surfaces waters of the inlet and sound was salinity-driven with a strong pycnocline present at 1.5-7.0 m down Alberni Inlet. Transects for vertical profiles of CTD and *in vivo* chlorophyll fluorescence (IFL) showed significant spatial variations in vertical density and IFL structure, and short-term temporal variability near areas of tidal mixing. Deep chlorophyll maxima at depths down to 10 m were common in Barkley Sound.

Nutrient depletion (nitrate, phosphate, and silicate) of the surface waters in Trevor, Imperial Eagle, and Loudoun channels, and outer Alberni Inlet indicated the spring phytoplankton bloom was in progress throughout much of the sound by late April. Higher ambient nutrient levels in the euphotic-zone were generally found in areas of estuarine entrainment at the head of the inlet, near zones of tidal mixing, and outside the mouth of Barkley Sound in waters affected by deep wind mixing and advection of nutrient-rich water from upwelling along the continental shelf.

Euphotic-zone primary production (mgC m^{-3} h^{-1}) was very low at the head of Alberni Inlet (3.8), with highest levels recorded in the outer inlet, inner Loudoun Channel, and off Amphitrite Point (23.7-28.4), and intermediate levels in the rest of the sound (14.4-16.5). Chlorophyll levels were significantly correlated (r=0.85) with primary production and ranged from 2.2 μg L^{-1} at the head of the inlet up to 10.3-12.5 μg L^{-1} in Trevor and inner Loudoun and Imperial Eagle channels. The picophytoplankton size-fraction (0.2-2.0 μm) was a minor component of the phytoplankton in April, averaging 15% of the total primary production and 10% of total chlorophyll biomass, while nanophytoplankton (2.0-20 μm) contributed most of the chlorophyll (53%) but only 24% of the production. Microphytoplankton (20-200 μm) averaged 36% of the chlorophyll but dominated primary production (60%). Euphotic-zone densities of picophytoplankton (>98% *Synechococcus* sp.) and bacteria were generally low (<6.6 10^3 mL^{-1} and <12.9 10^6 mL^{-1} respectively) but typical of spring in temperate coastal waters.

Filter-fractionation of particulate carbon (PC), nitrogen (PN), phosphorus (PP), and chlorophyll, and comparisons of elemental composition ratios for the various size-fractions showed a significant contribution to total particulates (8-20%) by dissolved and colloidal organic matter passing a 0.2-μm polycarbonate filter but retained by glass-fibre filters. The picoplankton size-fraction was dominated by bacteria (and possibly detritus), while the microplankton fraction contained variable amounts of microzooplankton. The nanoplankton fraction was relatively free of detrital and microzooplankton contamination, and was used to evaluate the nutritional status of the phytoplankton populations. Based on PC:PN and PN:PP elemental ratios, only the outer Alberni Inlet phytoplankton showed both PC:PN and PN:PP ratios indicating some degree of nitrogen deficiency in late April.

Comparisons of bacteria and nutrient depletion levels, as indices of *recent* phytoplankton productivity occurring prior to the cruise, with *current* levels of chlorophyll and primary production were used to determine the possible interactive effects of spring phytoplankton bloom-timing with cruise timing on the regional variations in phytoplankton biomass and production

observed in the sound. The comparisons suggest the cruise generally coincided with peak development of the spring phytoplankton bloom throughout much of the sound.

Sockeye smolts migrate through the inlet and sound during a highly temporally and spatially variable period for phytoplankton production. Although areas of the outer inlet and channels were clearly areas of high phytoplankton productivity in late April, the link between high spring phytoplankton production and the zooplankton food resources of juvenile sockeye is not yet clear. Interannual variations in the timing of spring plankton production, driven by oceanographic and climatic conditions, may be as important to the productivity of the foodchains for sockeye smolts as regional differences in plankton productivity. However, more information on the life-history, behaviour, and feeding activities of the important zooplankton prey species is required to determine the phytoplankton productivity conditions that lead to variations in food resources for migrating juvenile sockeye salmon in the spring.

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STATION: B1
AREA: China Creek
DATE: April 27, 1987
DEPTH: 125m
CONDITIONS: Clear, calm

LATITUDE: 49°08'
LONGITUDE: 124°48'
COMPENSATION DEPTH: 7.72m
EXTINCTION COEFFICIENT: 0.471

Table 1A. Physical and chemical data for specified depths in the water column, at station B1.

DEPTH (m)	Temp. (°C)	Salinity (ppt)	Nutrients ($\mu g\text{-at} \cdot L^{-1}$)			Total Alkalinity ($mg \cdot L^{-1}$ as $CaCO_3$)
			Silicate	Nitrate	Phosphate	
0.5	11.17	8.46	30.6	1.8	0.33	12.65
1.0	11.26	8.75	32.2	2.4	0.38	13.79
2.0	10.08	23.55	37.4	2.7	0.63	13.57
3.0	9.65	26.10	35.0	7.7	0.97	19.31
5.0	9.26	30.53	33.3	13.1	1.57	24.76
7.0	9.25	30.95	33.3	13.3	1.43	25.10
10.0	9.26	31.14	36.4	13.6	1.44	25.57
15.0	9.28	31.31	37.0	14.6	1.91	30.09

Table 1B. Filter-fractionated data taken at specified depths, at station B1, for: particulate nitrogen (PN), particulate carbon (PC), particulate phosphorus (PP), and chlorophyll (CHL). Size fractions are in microns, and concentrations are as $\mu g\text{-}N \cdot L^{-1}$, $\mu g\text{-}C \cdot L^{-1}$, $\mu g\text{-}P \cdot L^{-1}$, and $\mu g\text{-}CHL \cdot L^{-1}$ respectively.

Fractionated Parameter	DEPTH (m)	1.0	3.0	5.0	Mean
PN	<0.2	2.4	4.5	12.2	6.4
	<2.0	35.9	18.3	13.9	22.7
	<20.0	55.9	18.4	42.3	38.7
	<200.0	61.1	41.0	/	51.1
PC	<0.2	102.3	135.9	153.4	130.5
	<2.0	332.7	244.0	265.1	280.6
	<20.0	481.2	310.5	361.7	384.5
	<200.0	571.4	358.7	/	465.1
PP	<0.2	0.94	0.71	0.44	0.70
	<2.0	/	0.88	/	0.88
	<20.0	4.75	4.22	2.43	3.80
	<200.0	6.99	4.39	3.09	4.82
CHL	<0.2	<0.18	<0.18	<0.18	<0.18
	<2.0	0.20	0.65	0.58	0.48
	<20.0	0.85	2.76	2.45	2.02
	<200.0	0.99	2.65	4.08	2.57

Table 1C. Data for specified depths, at station B1, in the water column for: phototrophic picoplankton, bacteria, total chlorophyll, and filter-fractionated primary production where all size fractions are in microns.

DEPTH (m)	Phototrophic Picoplankton ($x10^3 \cdot mL^{-1}$)	Bacteria ($x10^5 \cdot mL^{-1}$)	Total Chlorophyll ($\mu gChl \cdot L^{-1}$)	Production (mg $C \cdot m^{-3} \cdot h^{-1}$) Size Fractions (µm) >0.2	>2.0	>20.0
0.5			2.60	7.11	5.90	2.65
1.0	0.85	6.73	3.67	9.47	9.45	2.46
2.0			2.91	7.17	6.52	2.14
3.0	1.61	4.80	3.52	3.80	2.83	1.04
5.0	1.01	3.70	1.39	1.72	1.34	<0.50
7.0			0.72	0.57	0.60	<0.50
10.0	0.37	/	0.49	<0.50	<0.50	<0.50
15.0			<0.18	<0.50	<0.50	<0.50

STATION: B2
AREA: Nahmint
DATE: April 28, 1987
DEPTH: 263m
CONDITIONS: Overcast, light chop

LATITUDE: 49°04'
LONGITUDE: 124°51'
COMPENSATION DEPTH: 6.98m
EXTINCTION COEFFICIENT: 0.634

Table 2A. Physical and chemical data for specified depths in the water column, at station B2.

DEPTH (m)	Temp. (°C)	Salinity (ppt)	Nutrients ($\mu g\text{-}at \cdot L^{-1}$) Silicate	Nitrate	Phosphate	Total Alkalinity ($mg \cdot L^{-1}$ as $CaCO_3$)
0.5	11.65	25.46	25.7	2.5	0.56	20.01
1.0	11.45	25.60	25.2	3.5	0.63	21.63
2.0	11.33	25.84	25.6	4.5	0.76	21.14
3.0	11.10	26.20	27.0	5.5	0.84	21.80
5.0	10.58	26.88	26.1	6.3	0.95	21.94
7.0	9.95	29.30	28.4	9.5	1.24	24.60
10.0	9.28	31.34	33.1	12.3	1.77	25.01
15.0	9.25	31.57	38.8	13.9	1.79	25.14

Table 2B. Filter-fractionated data taken at specified depths, at station B2, for: particulate nitrogen (PN), particulate carbon (PC), particulate phosphorus (PP), and chlorophyll (CHL). Size fractions are in microns, and concentrations are as $\mu g\text{-}N \cdot L^{-1}$, $\mu g\text{-}C \cdot L^{-1}$, $\mu g\text{-}P \cdot L^{-1}$, and $\mu g\text{-}CHL \cdot L^{-1}$ respectively.

Fractionated Parameter	DEPTH (m)	1.0	3.0	5.0	Mean
PN	<0.2	5.5	9.6	3.7	6.3
	<2.0	12.9	13.6	14.6	13.7
	<20.0	73.5	79.0	72.4	75.0
	<200.0	115.9	114.3	84.7	105.0
PC	<0.2	78.9	64.4	84.5	75.9
	<2.0	126.4	135.4	125.5	129.1
	<20.0	440.9	458.8	417.2	439.0
	<200.0	628.0	637.1	465.8	577.0
PP	<0.2	0.37	0.39	0.76	0.51
	<2.0	1.29	1.62	1.60	1.50
	<20.0	3.51	3.70	3.46	3.56
	<200.0	5.29	5.11	4.52	4.97
CHL	<0.2	0.45	<0.18	<0.18	<0.27
	<2.0	0.42	0.56	0.56	0.51
	<20.0	7.44	7.75	8.46	7.88
	<200.0	>9.27	>9.27	>9.27	>9.27

Table 2C. Data for specified depths, at station B2, in the water column for: phototrophic picoplankton, bacteria, total chlorophyll, and filter-fractionated primary production where all size fractions are in microns.

DEPTH (m)	Phototrophic Picoplankton ($x10^3 \cdot mL^{-1}$)	Bacteria ($x10^9 \cdot mL^{-1}$)	Total Chlorophyll ($\mu gChl \cdot L^{-1}$)	Production ($mg\ C \cdot m^{-3} \cdot h^{-1}$) Size Fractions (µm) >0.2	>2.0	>20.0
0.5			>9.27	38.89	36.80	20.53
1.0	1.32	4.42	9.07	41.86	40.85	14.66
2.0			8.76	34.62	27.86	14.84
3.0	0.96	3.66	>9.27	24.05	25.65	13.22
5.0	1.55	3.09	8.46	13.80	13.05	7.27
7.0			6.12	6.47	5.66	3.60
10.0	0.99	2.72	3.26	2.01	1.62	1.68
15.0			0.63	<0.50	<0.50	<0.50

STATION: B3
AREA: Inside Junction Passage
DATE: April 29, 1987
DEPTH: 260m
CONDITIONS: Overcast, calm

LATITUDE: 48°57'
LONGITUDE: 125°02'
COMPENSATION DEPTH: 6.94m
EXTINCTION COEFFICIENT: 0.653

Table 3A. Physical and chemical data for specified depths in the water column, at station B3.

DEPTH (m)	Temp. (°C)	Salinity (ppt)	Nutrients ($\mu g\text{-at} \cdot L^{-1}$)			Total Alkalinity ($mg \cdot L^{-1}$ as $CaCO_3$)
			Silicate	Nitrate	Phosphate	
0.5	12.26	25.17	3.7	<0.1	0.09	19.00
1.0	12.10	25.47	3.3	<0.1	0.05	16.70
2.0	11.95	25.80	4.0	<0.1	0.06	17.14
3.0	10.45	27.75	6.5	<0.1	0.07	19.39
5.0	9.42	31.03	14.0	3.2	0.62	22.97
10.0	9.25	31.49	22.5	9.1	1.23	24.42
15.0	9.23	31.59	28.1	12.9	1.48	25.49
20.0	9.22	31.71	28.3	13.3	1.61	25.32

Table 3B. Filter-fractionated data taken at specified depths, at station B3, for: particulate nitrogen (PN), particulate carbon (PC), particulate phosphorus (PP), and chlorophyll (CHL). Size fractions are in microns, and concentrations are as $\mu g\text{-}N \cdot L^{-1}$, $\mu g\text{-}C \cdot L^{-1}$, $\mu g\text{-}P \cdot L^{-1}$, and $\mu g\text{-}CHL \cdot L^{-1}$ respectively.

Fractionated Parameter	DEPTH (m)	1.0	3.0	5.0	Mean
PN	<0.2	/	11.3	9.3	10.3
	<2.0	32.3	22.4	28.2	27.6
	<20.0	43.3	50.0	0.0	54.4
	<200.0	73.7	85.7	110.5	90.0
PC	<0.2	/	168.5	137.2	152.9
	<2.0	244.6	227.3	206.1	226.0
	<20.0	522.7	457.5	493.0	491.1
	<200.0	1310.1	1159.5	964.9	1144.8
PP	<0.2	0.20	0.07	0.09	0.12
	<2.0	3.69	3.69	3.24	3.54
	<20.0	3.82	3.78	3.53	3.71
	<200.0	8.25	8.97	9.15	8.79
CHL	<0.2	0.56	<0.18	<0.18	<0.31
	<2.0	0.67	0.51	0.90	0.69
	<20.0	2.76	5.21	6.43	4.80
	<200.0	7.85	8.86	>9.27	>8.66

Table 3C. Data for specified depths, at station B3, in the water column for: phototrophic picoplankton, bacteria, total chlorophyll, and filter-fractionated primary production where all size fractions are in microns.

DEPTH (m)	Phototrophic Picoplankton ($x10^3 \cdot mL^{-1}$)	Bacteria ($x10^5 \cdot mL^{-1}$)	Total Chlorophyll ($\mu gChl \cdot L^{-1}$)	Production (mg $C \cdot m^{-3} \cdot h^{-1}$) Size Fractions (µm) >0.2	>2.0	>20.0
0.5			3.97	17.81	12.42	8.58
1.0	2.68	9.93	4.38	15.09	10.30	10.54
2.0			5.00	14.75	12.61	9.91
3.0			7.75	24.51	16.66	14.82
5.0	8.31	9.95	9.07	11.22	10.71	8.02
10.0	6.68	2.76	5.10	1.82	1.25	0.90
15.0			2.70	0.83	0.56	<0.50
20.0	0.93	4.09	1.18	<0.50	<0.50	<0.50

STATION: B4
AREA: Trevor Channel
DATE: April 30, 1987
DEPTH: 128m
CONDITIONS: Overcast, fog, light chop

LATITUDE: 48°52'
LONGITUDE: 125°08'
COMPENSATION DEPTH: 5.06m
EXTINCTION COEFFICIENT: 0.981

Table 4A. Physical and chemical data for specified depths in the water column, at station B4.

DEPTH (m)	Temp. (°C)	Salinity (ppt)	Nutrients ($\mu g\text{-}at \cdot L^{-1}$) Silicate	Nitrate	Phosphate	Total Alkalinity ($mg \cdot L^{-1}$ as $CaCO_3$)
0.5	11.57	28.34	3.8	<0.1	0.05	20.88
1.0	11.22	28.90	5.4	<0.1	0.10	20.88
2.0	10.81	29.36	4.2	<0.1	0.04	20.88
3.0	10.45	29.76	7.3	<0.1	0.20	23.07
5.0	9.87	30.96	11.8	1.0	0.41	24.39
10.0	9.74	31.05	16.5	5.1	0.84	24.77
15.0	9.53	31.25	19.8	9.0	1.34	25.76
20.0	9.30	31.53	30.2	13.4	1.64	25.82

Table 4B. Filter-fractionated data taken at specified depths, at station B4, for: particulate nitrogen (PN), particulate carbon (PC), particulate phosphorus (PP), and chlorophyll (CHL). Size fractions are in microns, and concentrations are as $\mu g\text{-}N \cdot L^{-1}$, $\mu g\text{-}C \cdot L^{-1}$, $\mu g\text{-}P \cdot L^{-1}$, and $\mu g\text{-}CHL \cdot L^{-1}$ respectively.

Fractionated Parameter	DEPTH (m)	3.0	5.0	10.0	Mean
PN	<0.2	12.4	12.5	6.3	10.4
	<2.0	29.9	27.6	23.5	27.0
	<20.0	64.7	83.1	65.6	71.1
	<200.0	99.0	153.4	133.8	128.7
PC	<0.2	125.7	132.7	101.7	120.0
	<2.0	211.0	232.0	167.5	203.5
	<20.0	584.1	547.4	432.7	521.4
	<200.0	1122.6	1100.7	684.3	969.2
PP	<0.2	/	0.92	0.81	0.87
	<2.0	2.92	3.04	2.06	2.67
	<20.0	3.14	3.18	2.33	2.88
	<200.0	4.92	5.25	4.62	4.93
CHL	<0.2	0.78	0.76	0.24	0.59
	<2.0	0.88	1.03	1.05	0.99
	<20.0	4.18	7.94	6.62	6.25
	<200.0	16.10	25.29	16.10	19.16

Table 4C. Data for specified depths, at station B4, in the water column for: phototrophic picoplankton, bacteria, total chlorophyll, and filter-fractionated primary production where all size fractions are in microns.

DEPTH (m)	Phototrophic Picoplankton ($x10^3 \cdot mL^{-1}$)	Bacteria ($x10^3 \cdot mL^{-1}$)	Total Chlorophyll ($\mu gChl \cdot L^{-1}$)	Production (mg $C \cdot m^{-3} \cdot h^{-1}$) Size Fractions (µm) >0.2	>2.0	>20.0
0.5			6.12	7.18	7.49	5.60
1.0	4.90	11.93	6.32	7.17	5.42	4.93
2.0			7.54	5.72	4.33	3.54
3.0			15.49	10.49	10.55	11.78
5.0	1.16	13.90	21.64	4.80	4.91	4.29
10.0	3.24	7.97	22.04	0.77	0.95	<0.50
15.0			10.82	<0.50	<0.50	<0.50
20.0	2.68	4.50	2.25	<0.50	<0.50	<0.50

STATION: B5
AREA: Inner Imperial Eagle Channel
DATE: April 26, 1987
DEPTH: 96m
CONDITIONS: Clear, moderate chop

LATITUDE: 48°58'
LONGITUDE: 125°07'
COMPENSATION DEPTH: 6.91m
EXTINCTION COEFFICIENT: 0.645

Table 5A. Physical and chemical data for specified depths in the water column, at station B5.

DEPTH (m)	Temp. (°C)	Salinity (ppt)	Nutrients (µg-at·L^{-1})			Total Alkalinity (mg·L^{-1} as $CaCO_3$)
			Silicate	Nitrate	Phosphate	
0.5	10.19	25.96	13.3	2.0	0.43	19.25
1.0	9.95	27.35	13.7	3.2	0.46	19.06
2.0	9.70	29.63	14.7	2.6	0.51	19.75
3.0	9.71	29.58	14.2	2.3	0.48	19.83
5.0	9.74	29.44	16.6	6.7	1.06	23.22
7.0	9.60	29.55	21.4	10.4	1.24	24.12
10.0	9.21	31.44	21.9	10.7	1.29	24.30
15.0	9.22	31.62	23.5	11.9	1.27	24.85

Table 5B. Filter-fractionated data taken at specified depths, at station B5, for: particulate nitrogen (PN), particulate carbon (PC), particulate phosphorus (PP), and chlorophyll (CHL). Size fractions are in microns, and concentrations are as µg-N·L^{-1}, µg-C·L^{-1}, µg-P·L^{-1}, and µg-CHL·L^{-1} respectively.

Fractionated Parameter	DEPTH (m)	1.0	3.0	5.0	Mean
PN	<0.2	12.1	4.1	4.4	6.9
	<2.0	18.4	17.1	14.2	16.6
	<20.0	53.0	52.7	55.9	55.4
	<200.0	88.7	91.9	60.5	80.4
PC	<0.2	149.1	136.8	129.6	138.5
	<2.0	252.3	156.7	/	204.5
	<20.0	418.4	514.1	436.7	456.4
	<200.0	706.2	779.8	464.4	650.1
PP	<0.2	0.64	0.51	0.27	0.47
	<2.0	1.84	1.83	1.84	1.84
	<20.0	5.85	6.45	6.19	6.16
	<200.0	7.75	8.78	6.32	7.62
CHL	<0.2	0.49	0.34	<0.18	<0.34
	<2.0	0.56	0.79	0.70	0.68
	<20.0	7.95	4.70	6.32	6.32
	<200.0	8.56	8.97	7.24	8.26

Table 5C. Data for specified depths, at station B5, in the water column for: phototrophic picoplankton, bacteria, total chlorophyll, and filter-fractionated primary production where all size fractions are in microns.

DEPTH (m)	Phototrophic Picoplankton ($x10^3 \cdot mL^{-1}$)	Bacteria ($x10^6 \cdot mL^{-1}$)	Total Chlorophyll ($\mu gChl \cdot L^{-1}$)	Production (mg $C \cdot m^{-3} \cdot h^{-1}$) Size Fractions (µm) >0.2	>2.0	>20.0
0.5			10.41	23.57	18.83	18.13
1.0	5.61	8.81	11.02	20.81	17.51	15.58
2.0			20.01	18.20	17.90	14.82
3.0	5.07	8.04	11.43	22.48	20.09	15.99
5.0	9.13	6.59	6.73	11.14	9.03	6.05
7.0			4.53	6.85	7.28	3.79
10.0			2.96	1.42	2.18	<0.50
15.0	1.47	3.96	1.64	0.57	1.13	<0.50

STATION: B6
AREA: Outer Imperial Eagle Channel
DATE: April 25, 1987
DEPTH: 96m
CONDITIONS: Clear, light chop

LATITUDE: 48°53'
LONGITUDE: 125°14'
COMPENSATION DEPTH: 9.24m
EXTINCTION COEFFICIENT: 0.472

Table 6A. Physical and chemical data for specified depths in the water column, at station B6.

DEPTH (m)	Temp. (°C)	Salinity (ppt)	Nutrients ($\mu g\text{-at} \cdot L^{-1}$) Silicate	Nitrate	Phosphate	Total Alkalinity ($mg \cdot L^{-1}$ as $CaCO_3$)
0.5	10.34	28.30	4.3	0.1	0.21	21.36
1.0	10.35	28.31	3.8	0.1	0.21	21.91
2.0	10.36	28.34	3.3	<0.1	0.21	21.78
3.0	10.30	28.50	3.6	<0.1	0.21	22.04
5.0	10.24	28.86	4.0	0.1	0.27	22.15
10.0	9.60	30.46	21.9	11.6	1.33	25.04
15.0	9.22	31.27	14.3	6.8	1.45	25.22
20.0	9.25	31.42	22.9	11.6	1.39	18.93

Table 6B. Filter-fractionated data taken at specified depths, at station B6, for: particulate nitrogen (PN), particulate carbon (PC), particulate phosphorus (PP), and chlorophyll (CHL). Size fractions are in microns, and concentrations are as $\mu g\text{-}N \cdot L^{-1}$, $\mu g\text{-}C \cdot L^{-1}$, $\mu g\text{-}P \cdot L^{-1}$, and $\mu g\text{-}CHL \cdot L^{-1}$ respectively.

Fractionated Parameter	DEPTH (m)	1.0	5.0	10.0	Mean
PN	<0.2	4.4	9.6	1.4	5.1
	<2.0	21.8	27.2	13.3	20.8
	<20.0	50.5	54.7	28.1	44.4
	<200.0	85.2	99.7	30.0	71.6
PC	<0.2	95.0	158.8	76.9	110.2
	<2.0	237.6	191.0	114.8	181.1
	<20.0	372.7	385.2	212.7	323.5
	<200.0	675.6	676.8	196.2	516.2
PP	<0.2	0.34	0.41	0.13	0.29
	<2.0	2.05	2.73	1.15	1.98
	<20.0	5.50	6.28	2.79	4.86
	<200.0	9.88	12.08	2.83	8.26
CHL	<0.2	<0.18	<0.18	<0.18	<0.18
	<2.0	0.90	1.24	0.69	0.94
	<20.0	5.10	4.49	2.70	4.10
	<200.0	6.83	7.64	3.31	5.93

Table 6C. Data for specified depths, at station B6, in the water column for: phototrophic picoplankton, bacteria, total chlorophyll, and filter-fractionated primary production where all size fractions are in microns.

DEPTH (m)	Phototrophic Picoplankton ($x10^3 \cdot mL^{-1}$)	Bacteria ($x10^5 \cdot mL^{-1}$)	Total Chlorophyll ($\mu gChl \cdot L^{-1}$)	Production ($mg\ C \cdot m^{-3} \cdot h^{-1}$) Size Fractions ($\mu m$) >0.2	>2.0	>20.0
0.5			6.22	15.84	14.75	10.99
1.0	3.30	/	7.34	19.22	17.42	18.14
2.0			7.34	17.59	12.72	13.21
3.0			6.73	20.60	17.55	15.73
5.0	/	11.96	6.43	15.66	12.23	12.12
10.0	2.59	9.21	2.35	2.47	0.64	<0.50
15.0			2.04	<0.50	<0.50	<0.50
20.0	1.04	2.66	2.10	<0.50	<0.50	<0.50

STATION: B7
AREA: David Channel
DATE: April 22, 1987
DEPTH: 44m
CONDITIONS: Clear, calm

LATITUDE: 48°58'
LONGITUDE: 125°20'
COMPENSATION DEPTH: 9.10m
EXTINCTION COEFFICIENT: 0.485

Table 7A. Physical and chemical data for specified depths in the water column, at station B7.

DEPTH (m)	Temp. (°C)	Salinity (ppt)	Nutrients ($\mu g\text{-at} \cdot L^{-1}$)			Total Alkalinity ($mg \cdot L^{-1}$ as $CaCO_3$)
			Silicate	Nitrate	Phosphate	
0.5	10.67	25.82	2.4	<0.1	0.10	21.66
1.0	10.32	26.10	2.4	<0.1	0.10	21.30
2.0	10.10	28.54	2.6	<0.1	0.22	22.27
3.0	9.85	29.25	2.4	<0.1	0.15	22.85
5.0	9.68	30.11	5.2	0.1	0.42	24.39
7.0	9.45	30.41	6.9	0.4	0.53	25.91
10.0	9.23	30.89	18.6	7.9	1.27	25.60
15.0	9.20	31.12	27.0	10.9	1.52	25.67

Table 7B. Filter-fractionated data taken at specified depths, at station B7, for: particulate nitrogen (PN), particulate carbon (PC), particulate phosphorus (PP), and chlorophyll (CHL). Size fractions are in microns, and concentrations are as $\mu g\text{-}N \cdot L^{-1}$, $\mu g\text{-}C \cdot L^{-1}$, $\mu g\text{-}P \cdot L^{-1}$, and $\mu g\text{-}CHL \cdot L^{-1}$ respectively.

Fractionated Parameter	DEPTH (m)	1.0	3.0	5.0	Mean
PN	<0.2	/	/	8.5	8.5
	<2.0	24.0	27.8	38.2	30.0
	<20.0	46.5	43.4	42.2	44.0
	<200.0	52.8	73.2	91.4	72.5
PC	<0.2	/	/	187.2	187.2
	<2.0	238.3	250.3	295.2	261.3
	<20.0	416.5	370.0	392.0	392.8
	<200.0	510.7	741.5	790.9	681.0
PP	<0.2	0.71	0.19	0.44	0.45
	<2.0	1.82	2.12	2.50	2.15
	<20.0	3.89	4.70	5.12	4.57
	<200.0	5.77	7.31	9.19	7.42
CHL	<0.2	0.22	<0.18	<0.18	<0.19
	<2.0	0.54	0.88	0.99	0.80
	<20.0	2.86	4.28	3.52	3.55
	<200.0	3.31	7.75	10.01	7.02

Table 7C. Data for specified depths, at station B7, in the water column for: phototrophic picoplankton, bacteria, total chlorophyll, and filter-fractionated primary production where all size fractions are in microns.

DEPTH (m)	Phototrophic Picoplankton ($x10^3 \cdot mL^{-1}$)	Bacteria ($x10^9 \cdot mL^{-1}$)	Total Chlorophyll ($\mu gChl \cdot L^{-1}$)	Production (mg $C \cdot m^{-3} \cdot h^{-1}$) Size Fractions (µm) >0.2	>2.0	>20.0
0.5			2.10	7.25	6.11	3.10
1.0	4.11	9.61	2.96	6.94	5.18	5.50
2.0			4.08	16.46	9.99	6.18
3.0	4.09	11.90	3.26	15.44	8.67	5.16
5.0	2.59	10.07	20.42	47.15	29.02	21.54
7.0			18.79	55.20	23.28	15.88
10.0			17.12	10.71	7.35	3.94
15.0	0.23	3.07	1.42	<0.50	<0.50	<0.50

STATION: B8
AREA: Forbes Island
DATE: April 24, 1987
DEPTH: 52m
CONDITIONS: Clear, light chop

LATITUDE: 48°57'
LONGITUDE: 125°24'
COMPENSATION DEPTH: 9.50m
EXTINCTION COEFFICIENT: 0.399

Table 8A. Physical and chemical data for specified depths in the water column, at station B8.

DEPTH (m)	Temp. (°C)	Salinity (ppt)	Nutrients ($\mu g\text{-}at \cdot L^{-1}$) Silicate	Nitrate	Phosphate	Total Alkalinity ($mg \cdot L^{-1}$ as $CaCO_3$)
0.5	9.79	29.39	1.4	<0.1	0.08	20.30
1.0	9.71	29.70	0.9	<0.1	0.08	19.81
2.0	9.67	30.24	1.4	0.1	0.13	20.94
3.0	9.60	30.32	5.9	1.1	0.37	22.28
5.0	9.52	30.57	12.4	3.9	0.69	22.97
10.0	9.27	31.22	22.9	10.2	1.32	24.71
15.0	9.26	31.40	25.8	11.7	1.43	25.04
20.0	9.23	31.59	22.9	11.3	1.48	25.49

Table 8B. Filter-fractionated data taken at specified depths, at station B8, for: particulate nitrogen (PN), particulate carbon (PC), particulate phosphorus (PP), and chlorophyll (CHL). Size fractions are in microns, and concentrations are as $\mu g\text{-}N \cdot L^{-1}$, $\mu g\text{-}C \cdot L^{-1}$, $\mu g\text{-}P \cdot L^{-1}$, and $\mu g\text{-}CHL \cdot L^{-1}$ respectively.

DEPTH (m)	Phototrophic Picoplankton ($x10^3 \cdot mL^{-1}$)	Bacteria ($x10^3 \cdot mL^{-1}$)	Total Chlorophyll ($\mu gChl \cdot L^{-1}$)	Production (mg $C \cdot m^{-3} \cdot h^{-1}$) Size Fractions (µm) >0.2	>2.0	>20.0
0.5			3.26	6.65	3.91	2.70
1.0	2.79	12.04	3.57	7.01	3.84	4.39
2.0			5.21	11.28	10.59	8.46
3.0			10.41	26.34	20.97	18.57
5.0	1.72	6.07	13.05	22.77	25.87	15.53
10.0	0.45	4.97	3.47	5.81	2.03	1.37
15.0			1.59	2.14	<0.50	<0.50
20.0	0.37	4.92	0.90	<0.50	<0.50	<0.50

STATION: B9
AREA: 20km offshore Amphitrite Pt.
DATE: April 23, 1987
DEPTH: 97m
CONDITIONS: Clear, light chop

LATITUDE: 48°55'
LONGITUDE: 125°35'
COMPENSATION DEPTH: 10.00m
EXTINCTION COEFFICIENT: 0.394

Table 9A. Physical and chemical data for specified depths in the water column, at station B9.

DEPTH (m)	Temp. (°C)	Salinity (ppt)	Nutrients ($\mu g\text{-}at \cdot L^{-1}$) Silicate	Nitrate	Phosphate	Total Alkalinity ($mg \cdot L^{-1}$ as $CaCO_3$)
0.5	9.61	30.51	11.2	4.1	0.69	22.61
1.0	9.61	30.51	10.9	4.2	0.71	22.97
2.0	9.60	30.50	10.9	4.2	0.74	23.09
3.0	9.62	30.56	11.4	3.8	0.73	23.19
5.0	9.66	30.71	9.5	3.5	0.72	23.69
10.0	9.63	30.90	10.0	4.5	0.90	23.90
15.0	9.31	31.31	17.4	8.6	1.09	24.30
20.0	9.31	31.61	19.1	10.1	1.32	24.30

Table 9B. Filter-fractionated data taken at specified depths, at station B9, for: particulate nitrogen (PN), particulate carbon (PC), particulate phosphorus (PP), and chlorophyll (CHL). Size fractions are in microns, and concentrations are as $\mu g\text{-}N \cdot L^{-1}$, $\mu g\text{-}C \cdot L^{-1}$, $\mu g\text{-}P \cdot L^{-1}$, and $\mu g\text{-}CHL \cdot L^{-1}$ respectively.

Fractionated Parameter	DEPTH(m)	1.0	5.0	10.0	Mean
PN	<0.2	9.6	8.5	12.5	10.2
	<2.0	31.2	25.4	33.1	29.9
	<20.0	58.7	62.7	64.7	62.0
	<200.0	94.0	96.5	121.2	103.9
PC	<0.2	129.3	124.5	107.0	120.3
	<2.0	194.1	158.4	244.1	198.9
	<20.0	388.3	397.7	393.0	393.0
	<200.0	512.1	544.6	590.3	549.0
PP	<0.2	0.54	0.85	0.89	0.76
	<2.0	1.98	2.05	2.48	2.17
	<20.0	7.02	7.24	5.81	6.69
	<200.0	9.19	10.45	12.96	10.87
CHL	<0.2	0.27	0.31	<0.18	<0.25
	<2.0	0.70	0.60	1.17	0.82
	<20.0	6.53	3.68	4.09	4.77
	<200.0	8.76	7.24	7.44	7.81

Table 9C. Data for specified depths, at station B9, in the water column for: phototrophic picoplankton, bacteria, total chlorophyll, and filter-fractionated primary production where all size fractions are in microns.

DEPTH(m)	Phototrophic Picoplankton ($x10^3 \cdot mL^{-1}$)	Bacteria ($x10^5 \cdot mL^{-1}$)	Total Chlorophyll ($\mu gChl \cdot L^{-1}$)	Production (mg $C \cdot m^{-3} \cdot h^{-1}$) Size Fractions (µm) >0.2	>2.0	>20.0
0.5			8.97	44.27	23.21	19.61
1.0	1.16	7.30	8.05	39.20	22.74	21.99
2.0			8.86	37.74	23.11	20.40
3.0			10.01	29.33	25.02	18.22
5.0	1.24	9.85	8.86	28.89	29.43	24.87
10.0	1.35	7.81	8.05	8.16	8.57	6.77
15.0			4.08	3.22	1.28	0.69
20.0	0.62	8.01	2.70	<0.50	<0.50	<0.50

Table 10. Biological, nutrient, and fractionated particulate data for Somass River.

Parameter	Size Fraction (µm)	<0.2	<2.0	<20.0	<200.0	200-0.2
PC (µg-C•L^{-1})		108.8	129.5	244.4	295.5	150.7
PN (µg-N•L^{-1})		1.4	10.7	16.1	17.5	16.1
PP (µg-P•L^{-1})		0.00	0.76	1.24	1.91	1.91
Nitrate (µg-at N•L^{-1})	0.9					
Phosphate (µg-at P•L^{-1})	/					
Silicate (µg-at SiO_3•L^{-1})	39.6					
Bacteria (x10^5•mL^{-1})	2.39					
Picophytoplankton (x10^3•mL^{-1})	1.02					

Table 11. Mean or integrated mean values for selected physico-chemical and biological parameters averaged to the depth of the euphotic zone (1% of surface light). Units for PC, PN, and PP are $\mu g \cdot L^{-1}$.

	ALBERNI INLET			TREVOR CHANNEL	IMPERIAL EAGLE CHANNEL		LOUDOUN CHANNEL		AMPHIT. POINT
Station / Parameter	B1	B2	B3	B4	B5	B6	B7	B8	B9
Euphotic Zone (m)	7.72	6.98	6.94	5.06	6.91	9.24	9.10	9.50	10.00
Temperature (°C)	9.82	10.92	10.60	10.68	9.78	10.15	9.79	9.53	9.63
Salinity (ppt)	24.60	26.63	28.36	29.59	28.91	28.97	29.25	30.47	30.68
Nitrate (μg-at $N \cdot L^{-1}$)	8.61	5.61	1.68	0.21	4.75	2.31	0.76	3.79	3.96
Phosphate (μg-at $P \cdot L^{-1}$)	1.06	0.86	0.33	0.18	0.75	0.45	0.40	0.62	0.77
Silicate (μg-at $SiO_3 \cdot L^{-1}$)	33.83	26.41	9.13	6.83	15.76	7.35	5.52	10.68	10.28
PC (0.2 - 200μm)	334.6	501.1	991.9	849.2	511.6	406.0	493.8	/	428.7
PN (0.2 - 200μm)	44.7	98.7	79.7	118.3	73.5	66.5	64.0	/	93.7
PP (0.2 - 200μm)	4.12	4.46	8.67	4.06	7.15	7.97	6.97	/	10.11
Picophytoplankton ($x10^3 \cdot mL^{-1}$)	1.16	1.28	5.50	3.03	6.60	3.30	3.60	2.26	1.25
Bacteria ($x10^3 \cdot mL^{-1}$)	5.08	3.72	9.94	12.92	7.81	11.96	10.53	9.06	8.32
Chlorophyll ($\mu g \cdot L^{-1}$)	2.19	8.50	6.93	12.46	10.25	5.84	12.16	8.24	8.78
Production (mg $C \cdot m^{-2} \cdot h^{-1}$)	3.84	23.67	15.22	7.37	16.46	14.41	28.37	15.99	26.59
Production/Chlorophyll ($mgC \cdot h^{-1} \cdot mgChl^{-1}$)	1.75	2.78	2.20	0.59	1.61	2.47	2.33	1.94	3.03

Table 12. Normalized (0 to 1) relative rankings by selected primary productivity parameters for each station.

		ALBERNI INLET			TREVOR CHANNEL	IMPERIAL EAGLE CHANNEL		LOUDOUN CHANNEL		AMPHIT. POINT
Normalized Parameter	Station	B1	B2	B3	B4	B5	B6	B7	B8	B9
Recent Productivity										
Nutrient Depletion		0.00	0.28	0.84	0.98	0.48	0.79	0.89	0.63	0.57
Bacteria		0.15	0.00	0.68	1.00	0.44	0.90	0.74	0.58	0.50
MEAN		0.08	0.14	0.76	0.99	0.46	0.85	0.82	0.61	0.54
Current Productivity										
Chlorophyll		0.00	0.61	0.46	1.00	0.78	0.36	0.97	0.59	0.64
Primary Production		0.00	0.81	0.46	(0.14)	0.51	0.43	1.00	0.50	0.93
MEAN		0.00	0.71	0.46	(0.57)	0.65	0.40	0.99	0.55	0.79

FIGURES

Fig. 1. Map of Barkley Sound and Alberni Inlet.

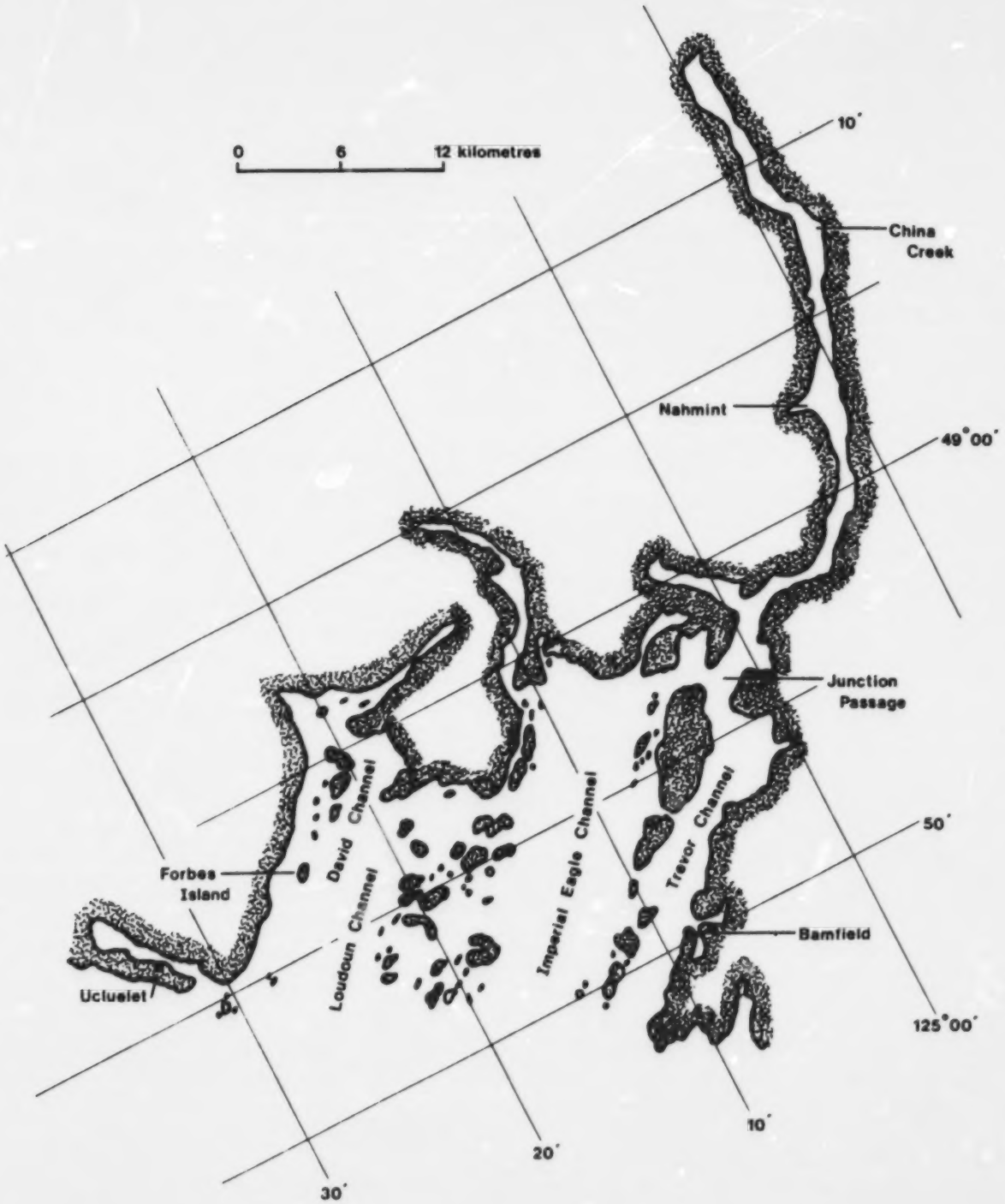

0
6
12 kilometres
10'
China Creek
Nahmint
49°00'
Junction Passage
50'
Bamfield
125°00'
10'
20'
30'
Forbes Island
Ucluelet
David Channel
Loudoun Channel
Imperial Eagle Channel
Trevor Channel

Fig. 2. Map of Barkley Sound and Alberni Inlet showing locations of the primary production stations (B1-B9) and the transect stations for CTD and *in vivo* chlorophyll casts conducted along Alberni Inlet (A1-A11), Trevor Channel (T0-T7), Imperial Eagle Channel (I1-I9), and Loudoun Channel (L1-L13). Stations with more than one station code (e.g. B3) were resampled during different transects.

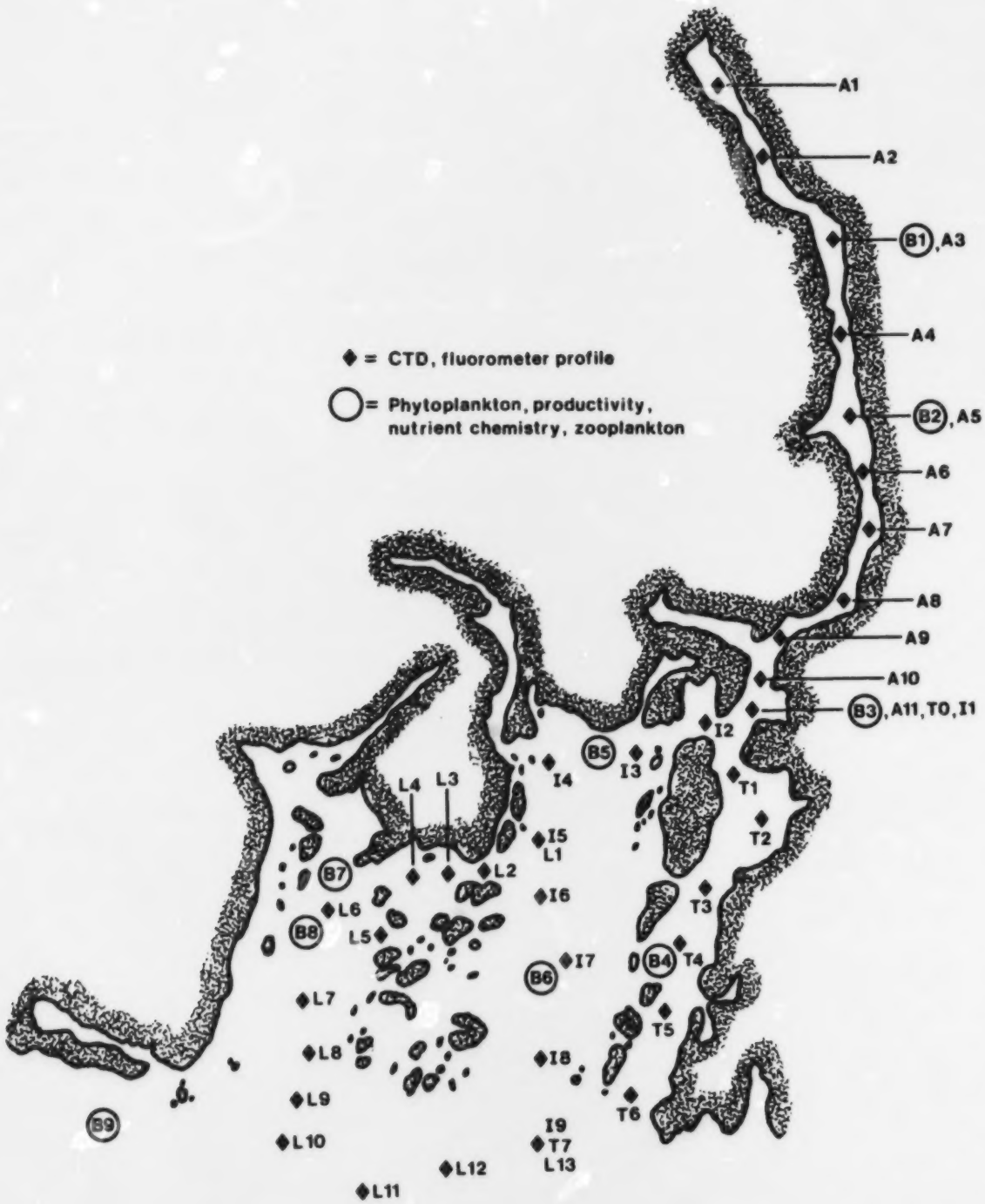

◆ = CTD, fluorometer profile
○ = Phytoplankton, productivity, nutrient chemistry, zooplankton
A1
A2
B1, A3
A4
B2, A5
A6
A7
A8
A9
A10
B3, A11, T0, I1
I2
B5
I3
I4
T1
L4
L3
I5
L1
T2
B7
L2
I6
T3
L6
B8
L5
I7
B6
B4
T4
L7
T5
L8
I8
L9
T6
B9
I9
L10
T7
L13
L12
L11

Fig. 3. Comparison of total extracted chlorophyll levels ($\mu g\ L^{-1}$) in whole water samples and samples prescreened through 200-μm nylon mesh, averaged over the euphotic zone at stations B1-B7 and B9. Line is the 1:1 ratio for no significant difference between samples.

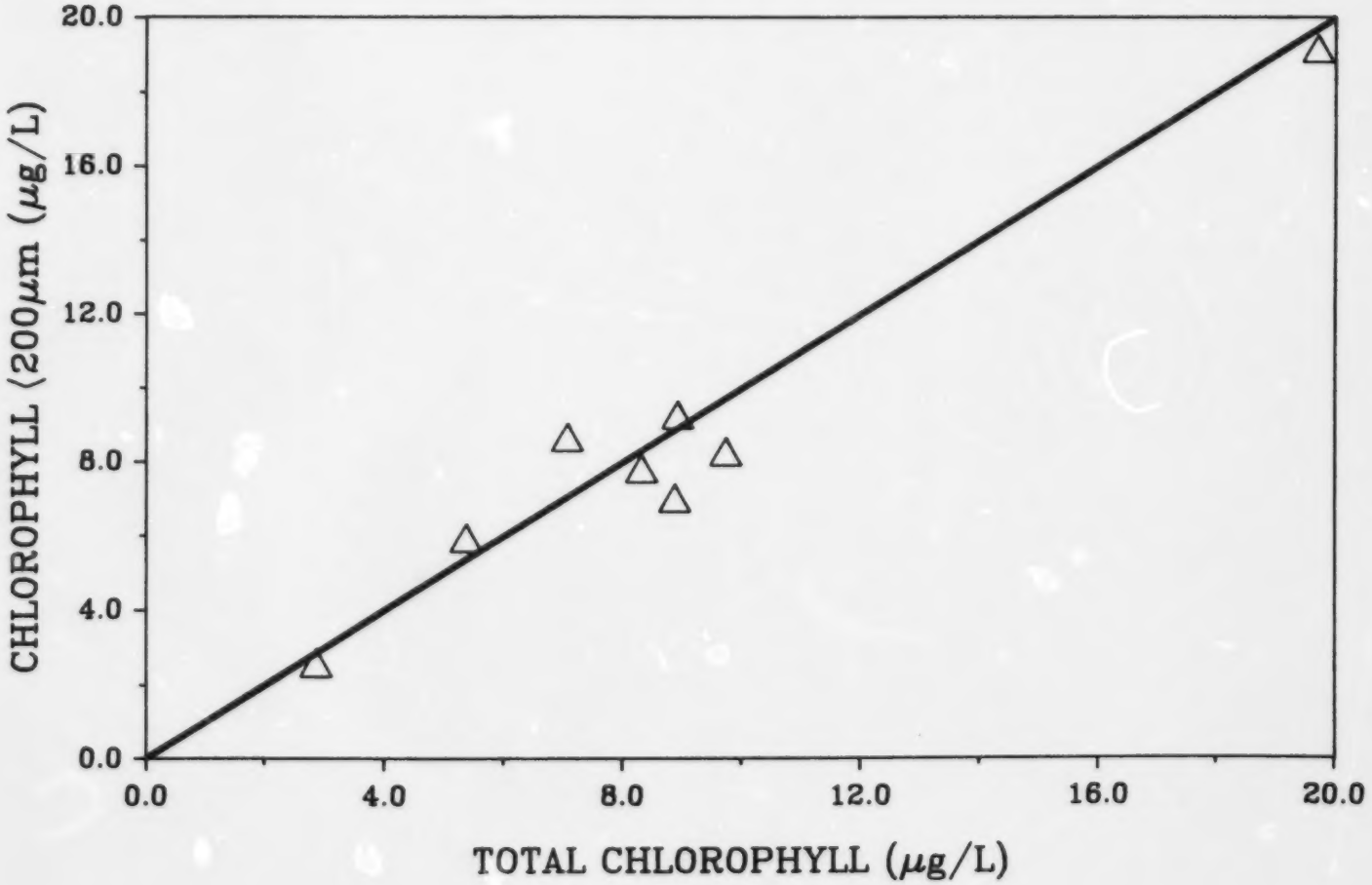

20.0
16.0
12.0
8.0
4.0
0.0
CHLOROPHYLL (200μm (μg/L)
0.0
4.0
8.0
12.0
16.0
20.0
TOTAL CHLOROPHYLL (μg/L)

Fig. 4. Vertical profiles of sigma-t density (dotted line) and relative *in vivo* chlorophyll fluorescence (solid line) obtained with a CTD and an *in situ* fluorometer at stations A1-A11 during the Alberni Inlet transect.

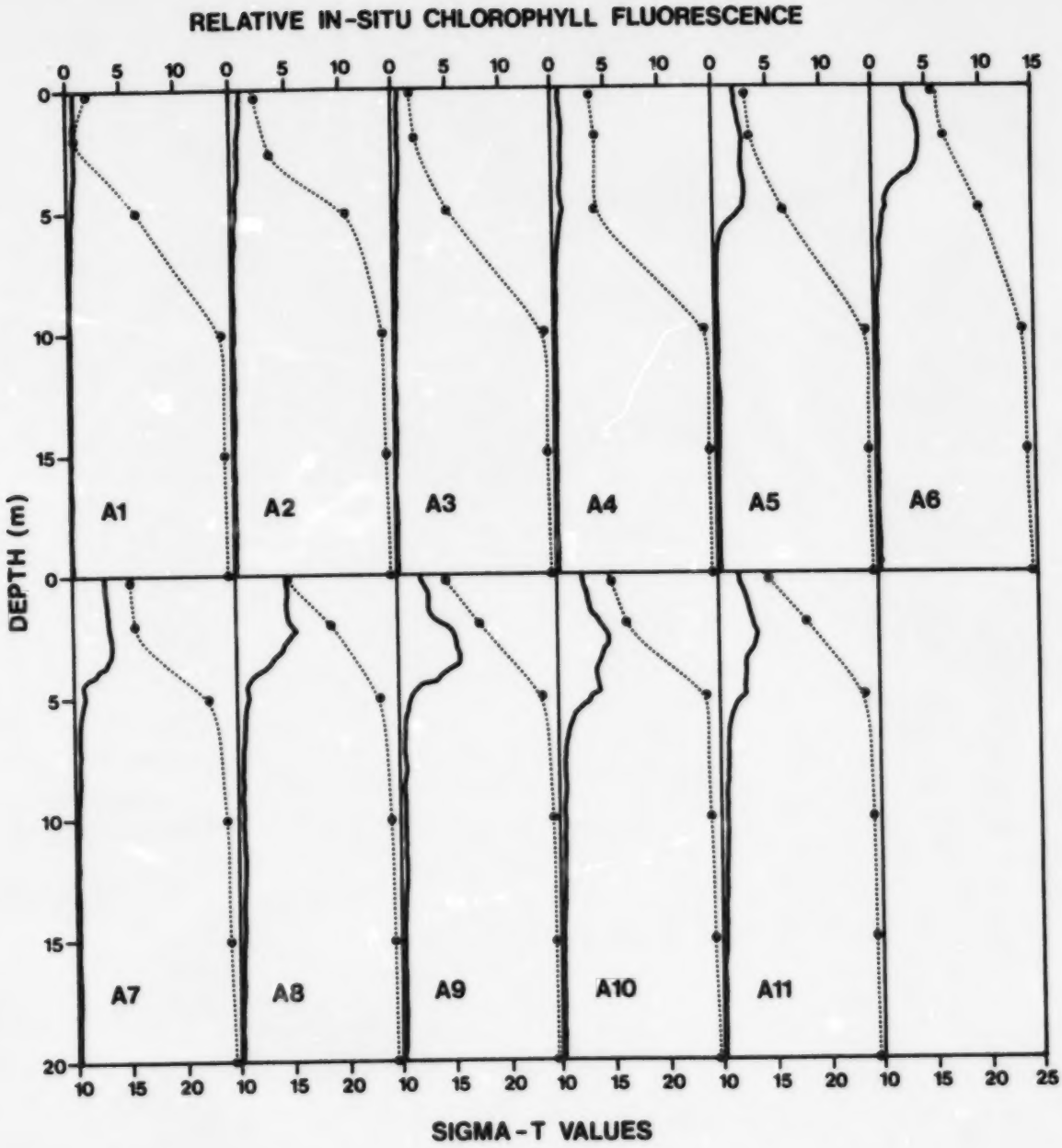

RELATIVE IN-SITU CHLOROPHYLL FLUORESCENCE
DEPTH (m)
A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A11
SIGMA-T VALUES

Fig. 5. Vertical profiles of sigma-t density (dotted line) and relative *in vivo* chlorophyll fluorescence (solid line) obtained with a CTD and an *in situ* fluorometer at stations T0-T7 during the Trevor Channel transect.

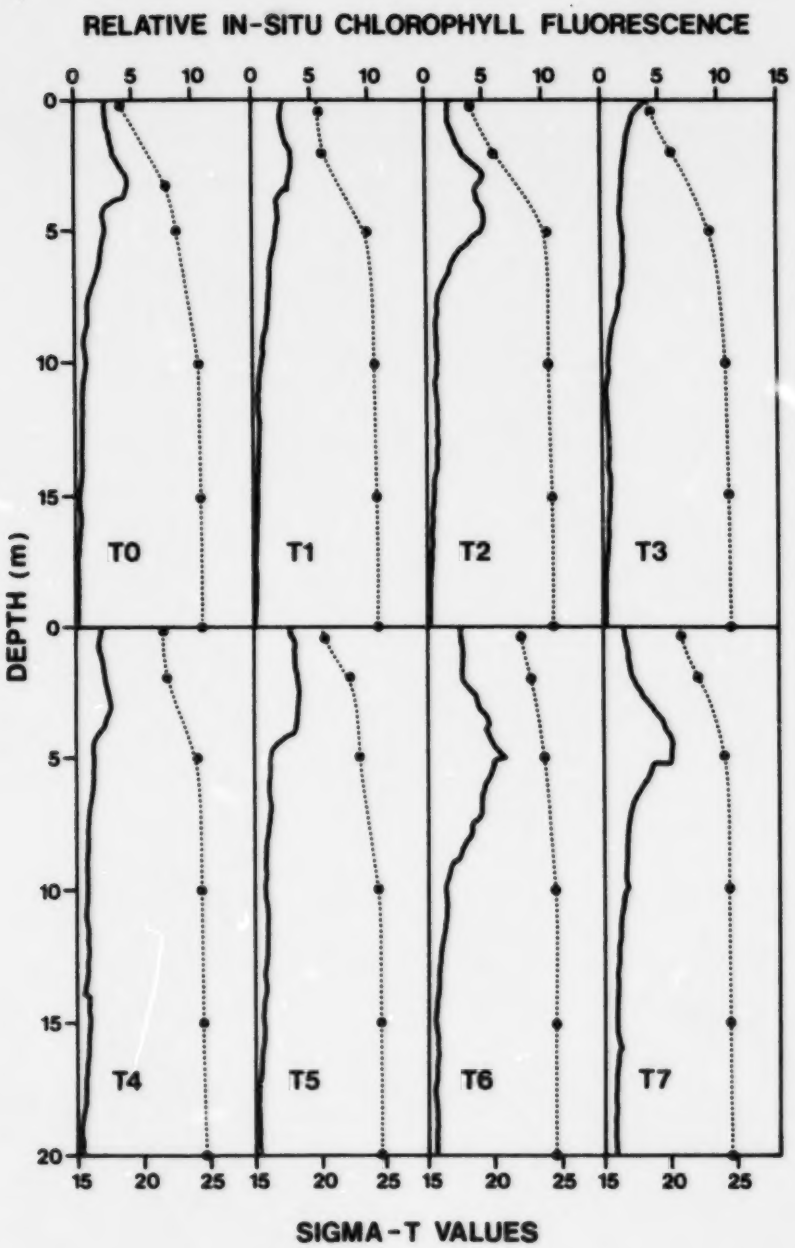

RELATIVE IN-SITU CHLOROPHYLL FLUORESCENCE
0 5 10 0 5 10 0 5 10 0 5 10 15
DEPTH (m)
0
5
10
15
20
T0
T1
T2
T3
T4
T5
T6
T7
15 20 25 15 20 25 15 20 25 15 20 25
SIGMA-T VALUES

Fig. 6. Vertical profiles of sigma-t density (dotted line) and relative *in vivo* chlorophyll fluorescence (solid line) obtained with a CTD and an *in situ* fluorometer at stations I1-I9 during the Imperial Eagle Channel transect.

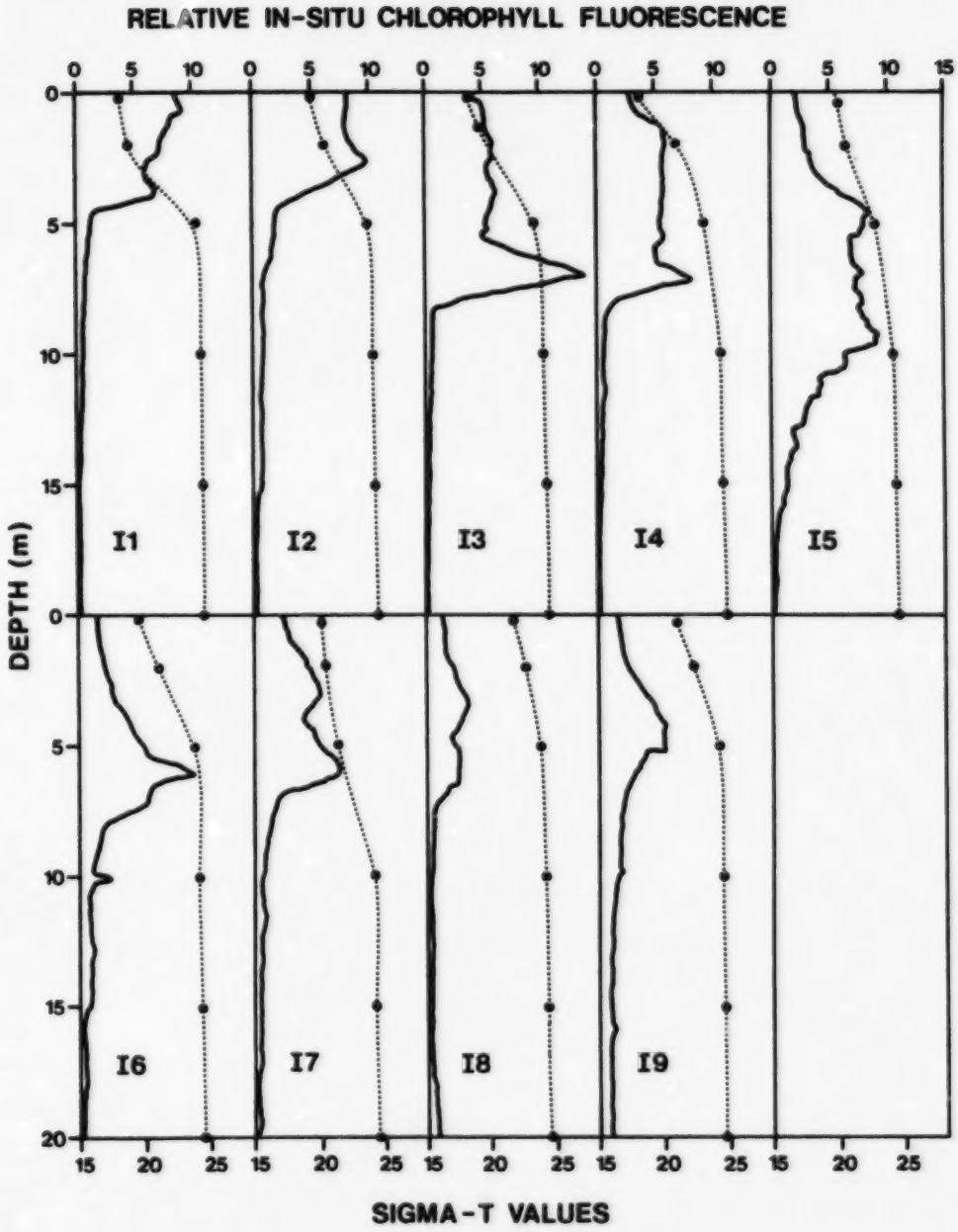

RELATIVE IN-SITU CHLOROPHYLL FLUORESCENCE
DEPTH (m)
I1
I2
I3
I4
I5
I6
I7
I8
I9
SIGMA-T VALUES

Fig. 7. Vertical profiles of sigma-t density (dotted line) and relative *in vivo* chlorophyll fluorescence (solid line) obtained with a CTD and an *in situ* fluorometer at stations L1-L8 during the Loudoun Channel transect.

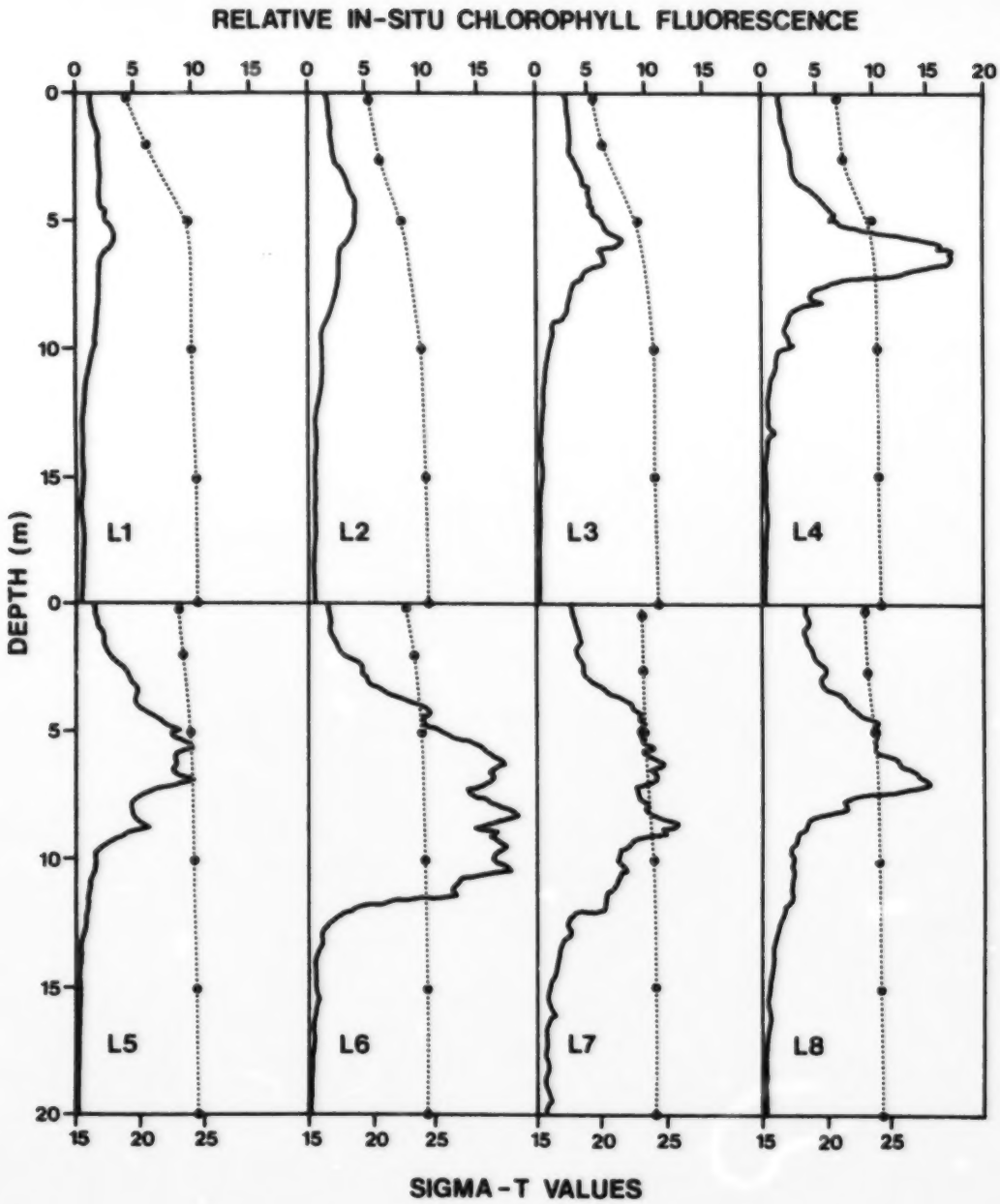

RELATIVE IN-SITU CHLOROPHYLL FLUORESCENCE
0 5 10 15 0 5 10 15 0 5 10 15 0 5 10 15 20
DEPTH (m)
0
5
10
15
20
L1
L2
L3
L4
L5
L6
L7
L8
15 20 25
SIGMA-T VALUES

Fig. 8. Vertical profiles of sigma-t density (dotted line) and relative *in vivo* chlorophyll fluorescence (solid line) obtained with a CTD and an *in situ* fluorometer at stations L9-L13 during the Loudoun Channel transect.

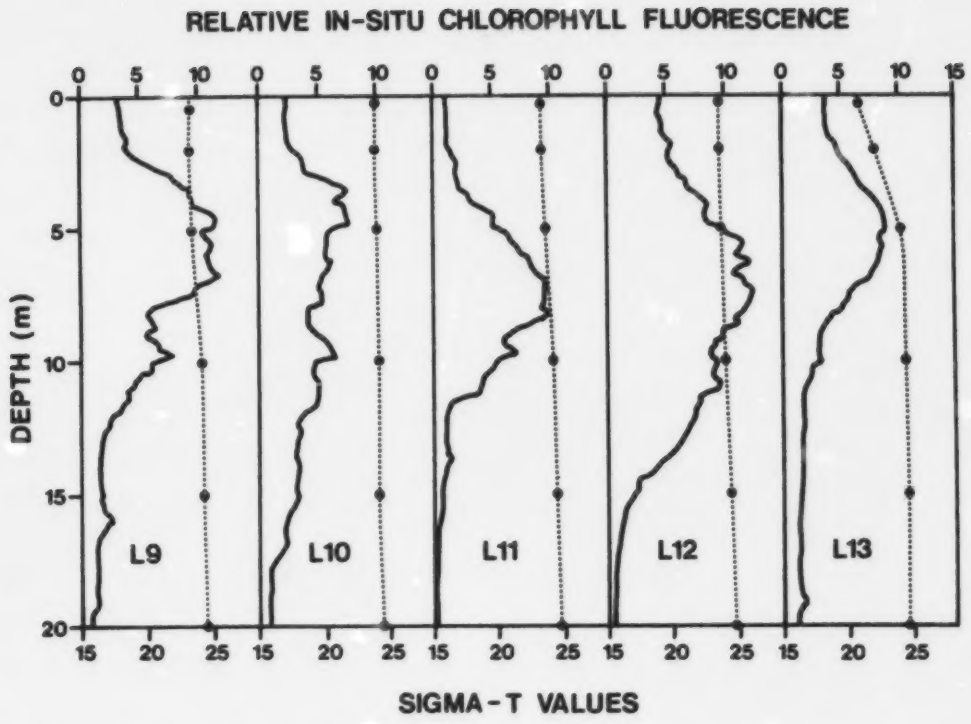

RELATIVE IN-SITU CHLOROPHYLL FLUORESCENCE
DEPTH (m)
0
5
10
15
20
L9
L10
L11
L12
L13
0 5 10 0 5 10 0 5 10 0 5 10 0 5 10 15
15 20 25 15 20 25 15 20 25 15 20 25 15 20 25
SIGMA-T VALUES

Fig. 9. Comparison of vertical profiles of relative *in vivo* chlorophyll fluorescence (solid line) with total extracted chlorophyll ($\mu g\ L^{-1}$) at discrete depths (bars) taken concurrently at the primary production stations.

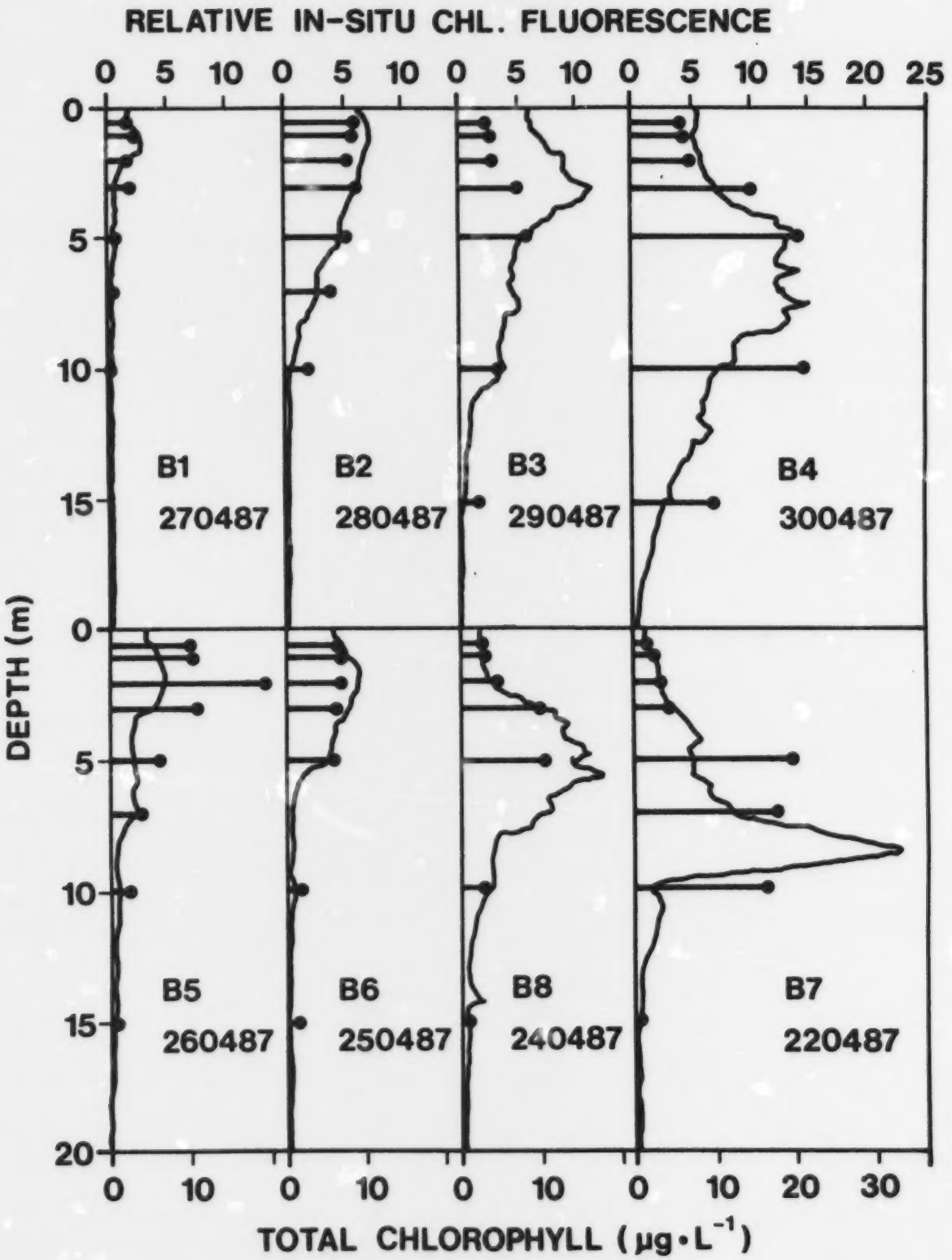

RELATIVE IN-SITU CHL. FLUORESCENCE
0 5 10 0 5 10 0 5 10 0 5 10 15 20 25
DEPTH (m)
0
5
10
15
20
B1
270487
B2
280487
B3
290487
B4
300487
B5
260487
B6
250487
B8
240487
B7
220487
0 10 0 10 0 10 0 10 20 30
TOTAL CHLOROPHYLL (µg•L⁻¹)

Fig. 10. Depth profiles of relative *in vivo* chlorophyll fluorescence (continuous solid line) and total *in situ* primary production (mgC m^{-3} h^{-1}) (discrete bars) at stations B1-B9. Hourly primary production rates were measured between 0930-1130 h at all stations.

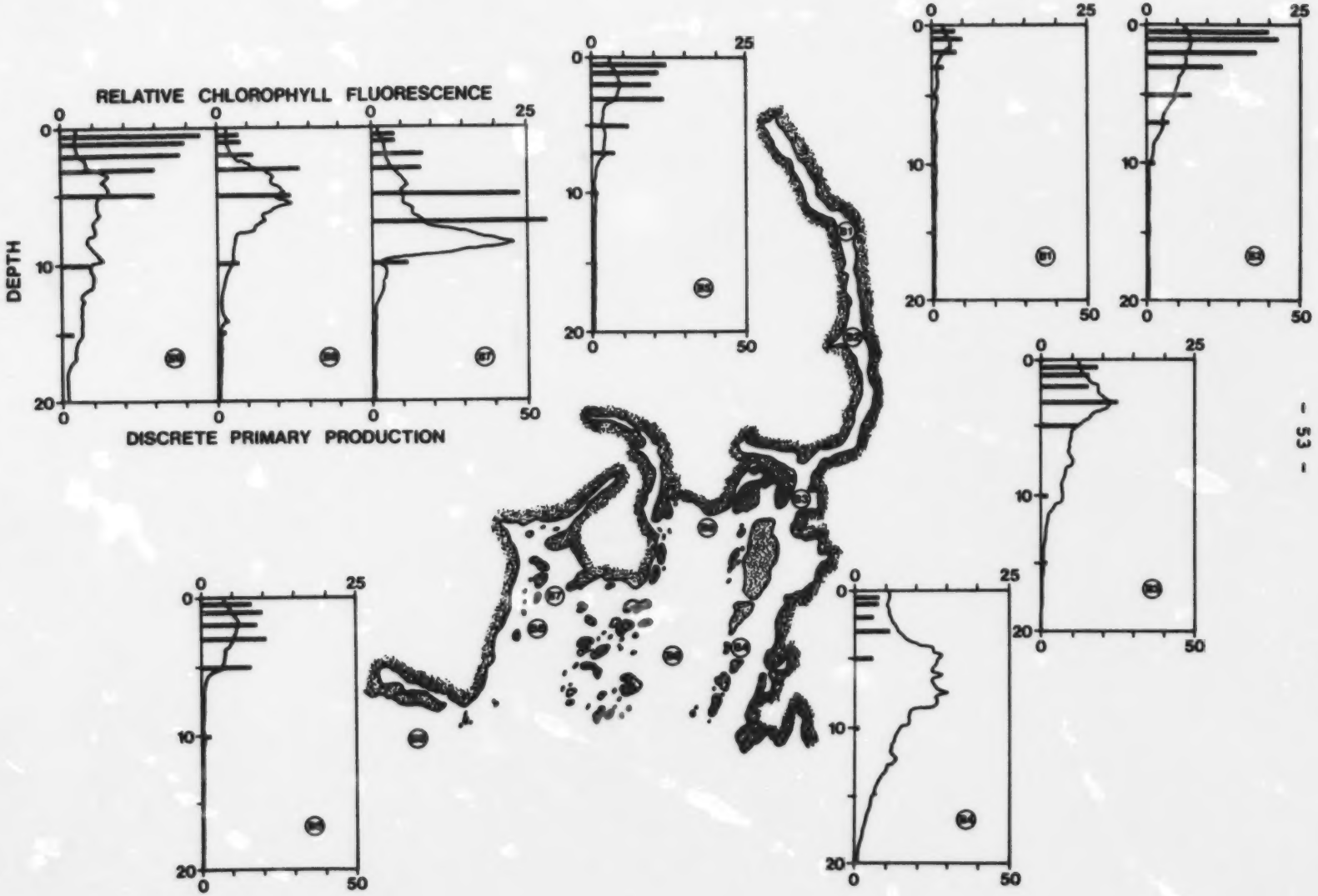

RELATIVE CHLOROPHYLL FLUORESCENCE
DISCRETE PRIMARY PRODUCTION
DEPTH
0
10
20
25
50

Fig. 11. Percent euphotic-zone contributions of the MICROplankton (20-200 μm), NANOplankton (2-20 μm), and PICOplankton (0.2-2 μm) size-fractions to total chlorophyll (CHL) and primary production (PROD) at stations B1-B9. Chlorophyll was not fractionated at station B8.

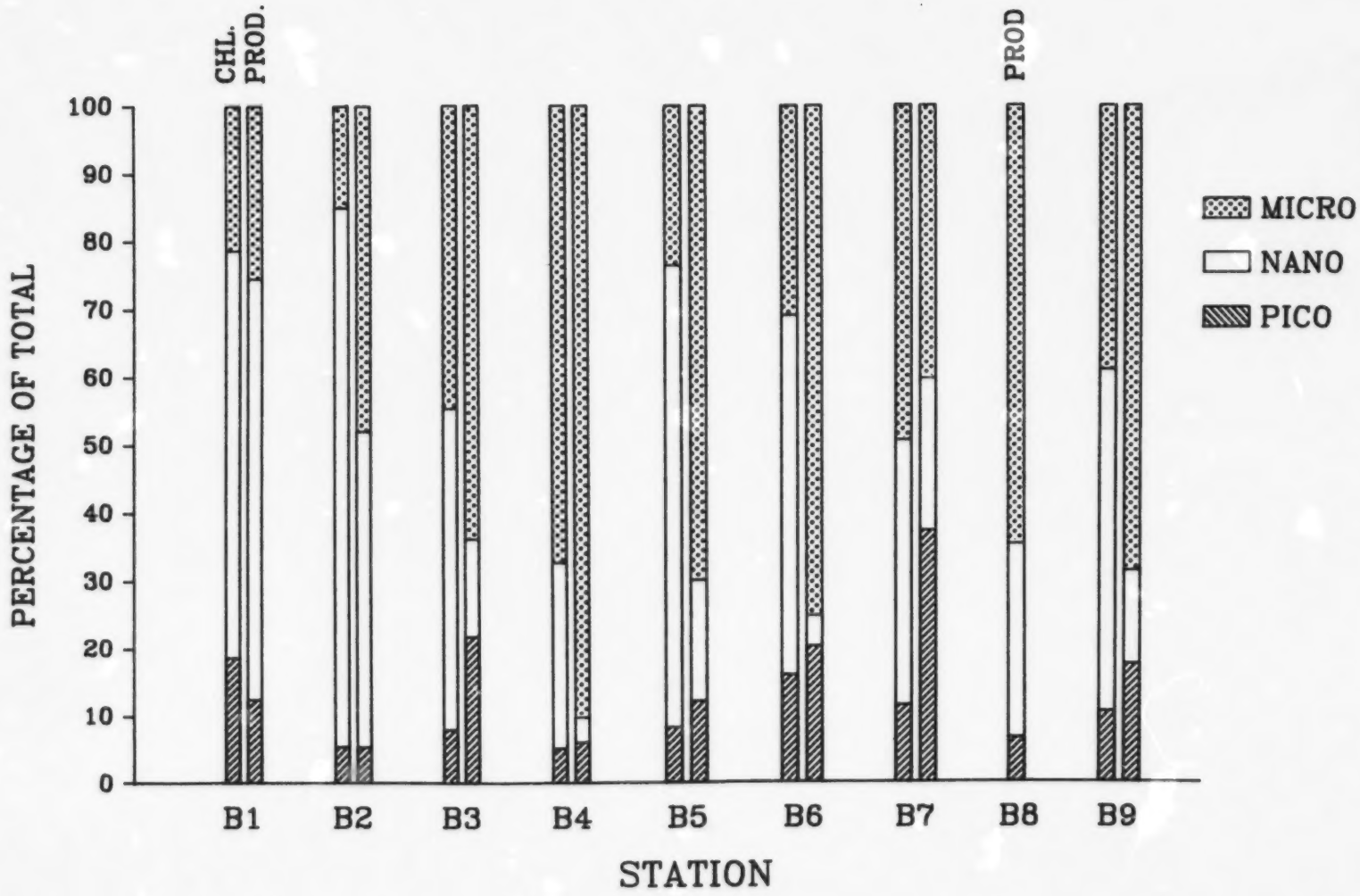

CHL.
PROD.
PROD
PERCENTAGE OF TOTAL
100
90
80
70
60
50
40
30
20
10
0
B1
B2
B3
B4
B5
B6
B7
B8
B9
STATION
MICRO
NANO
PICO

Fig. 12. Mean euphotic-zone particulate carbon:chlorophyll (μgC μgCHL^{-1}) ratios for three plankton size-fractions isolated by filter-fractionation at stations B1-B7 and B9.

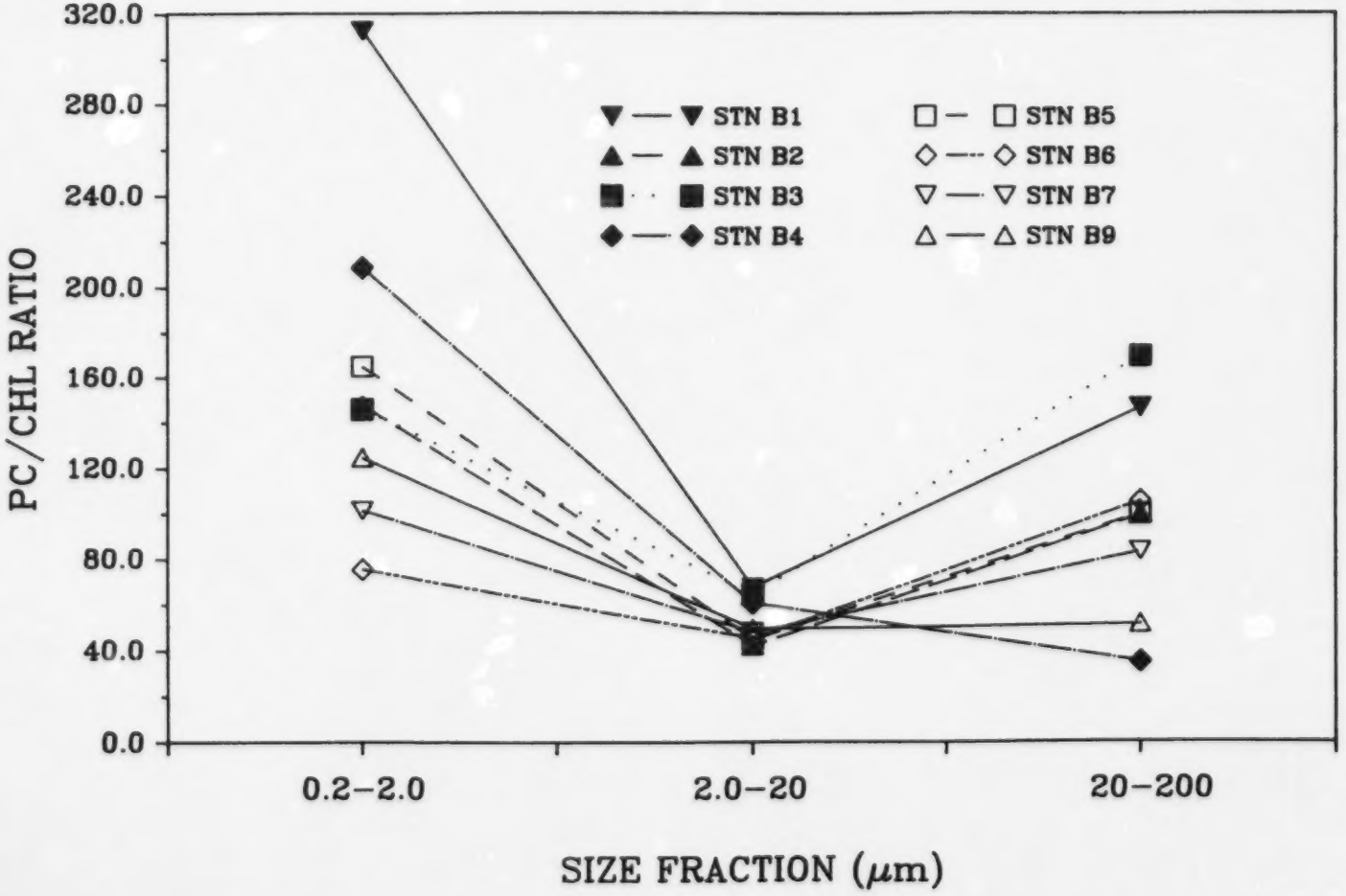

320.0
280.0
240.0
200.0
160.0
120.0
80.0
40.0
0.0
PC/CHL RATIO
STN B1
STN B2
STN B3
STN B4
STN B5
STN B6
STN B7
STN B9
0.2–2.0
2.0–20
20–200
SIZE FRACTION (μm)

Fig. 13. Mean euphotic-zone particulate carbon:nitrogen ($\mu gC\ \mu gN^{-1}$) ratios for four plankton size-fractions isolated by filter-fractionation at stations B1-B7 and B9. Hatched bar shows the PC:PN ratios for phytoplankton ranging from the Redfield ratio (5.7:1) to the 7:1 ratio of Healey and Hendzel (1980) for the onset of nitrogen limitation.

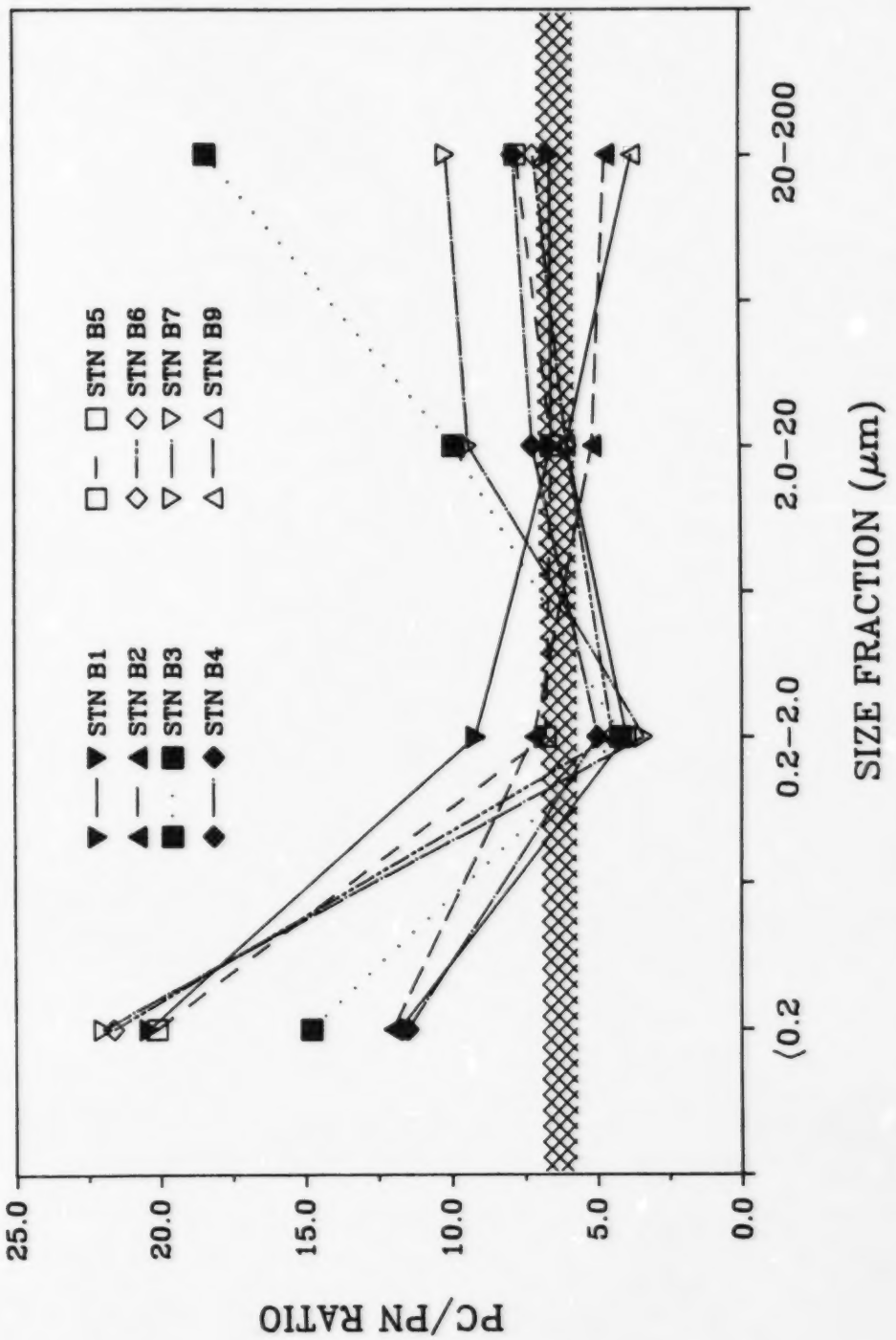
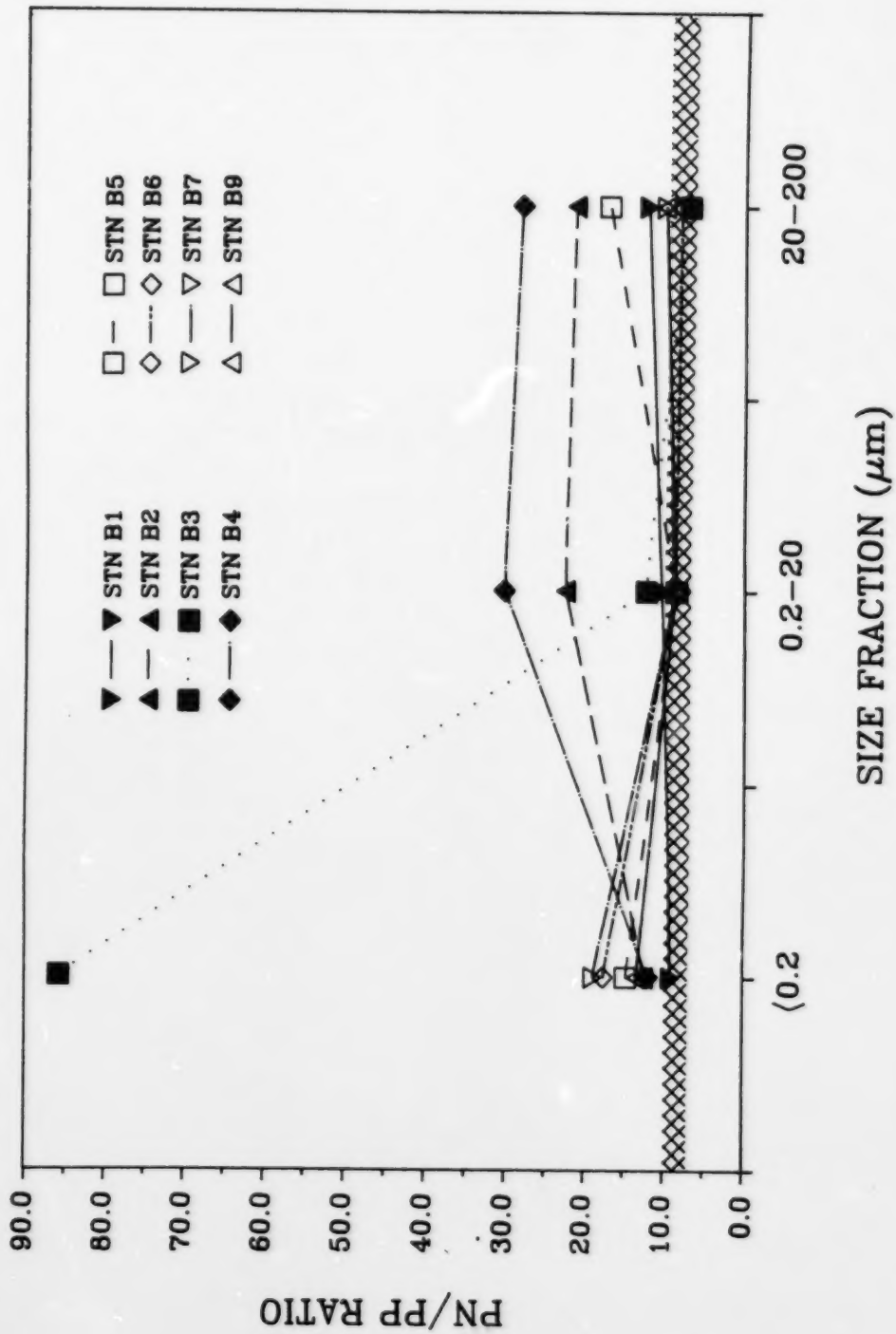

PC/PN RATIO
25.0
20.0
15.0
10.0
5.0
0.0
STN B1
STN B2
STN B3
STN B4
STN B5
STN B6
STN B7
STN B9
(0.2
0.2–2.0
2.0–20
20–200
SIZE FRACTION (μm)

Fig. 14. Mean euphotic-zone particulate nitrogen:phosphorus (μgN μgP^{-1}) ratios for three size-fractions isolated by filter-fractionation at stations B1-B7 and B9. Hatched bar shows the PN:PP ratios for phytoplankton ranging from the Redfield ratio (7.2:1) to the 10:1 ratio of Healey and Hendzel (1980) for the onset of nitrogen limitation.


PN/PP RATIO
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
STN B1
STN B2
STN B3
STN B4
STN B5
STN B6
STN B7
STN B9
⟨0.2
0.2–20
20–200
SIZE FRACTION (μm)